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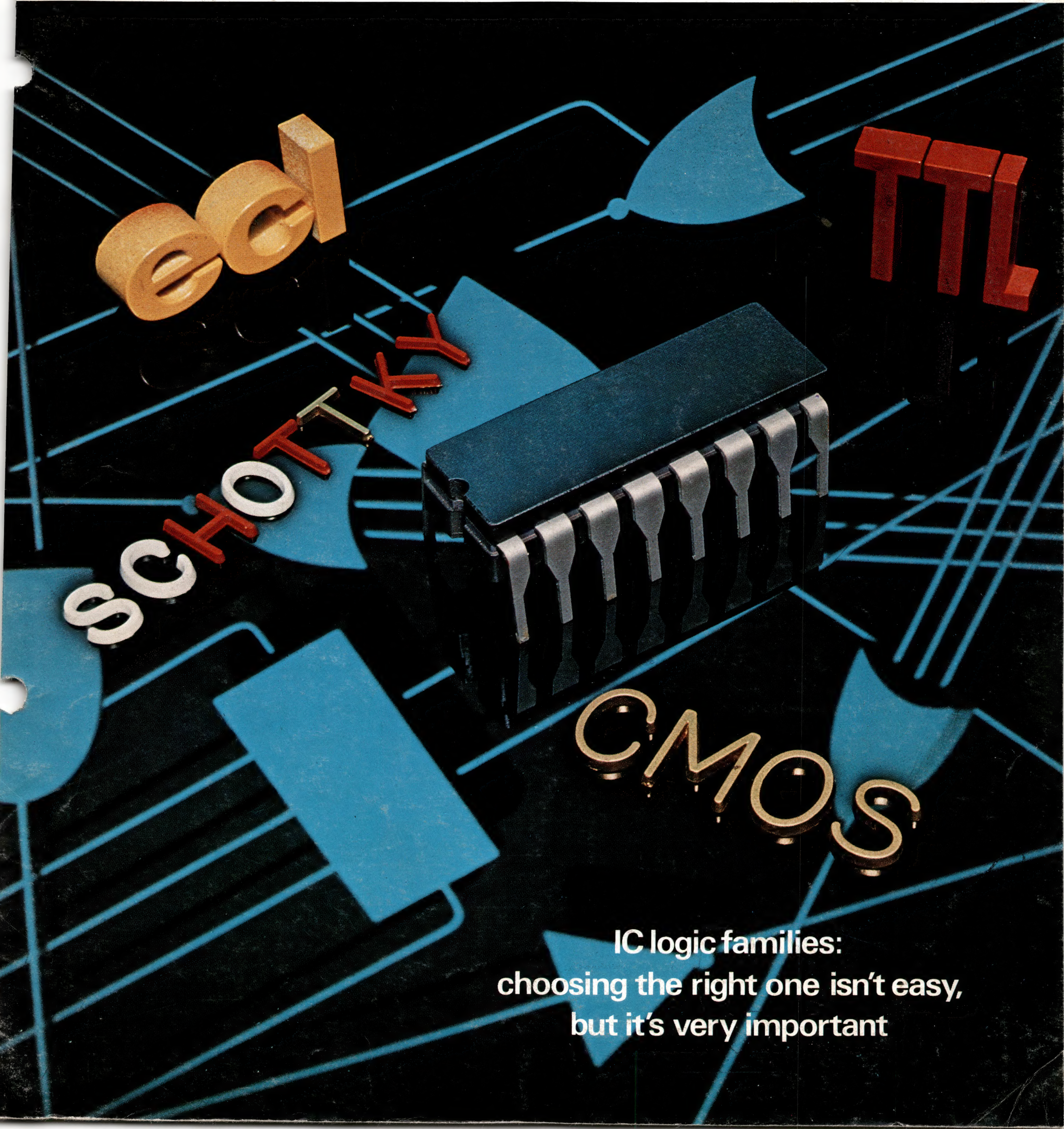

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VOLUME 19, NUMBER 19

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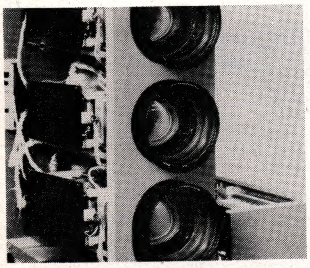
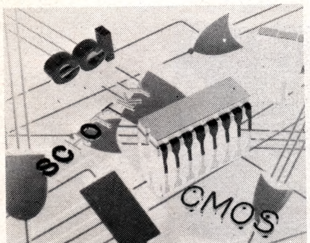


Projection TV ..... pg. 20



Logic families ..... pg. 30

Uniform DPM's ... pg. 82

COVER

As demand for digital logic functions continues to grow, well-known families expand in like manner. Each family serves a portion of the digital market, but there is much overlap in actual usage. The cover photo, courtesy of Motorola Semiconductor, highlights the families reviewed in the article starting on pg. 30.

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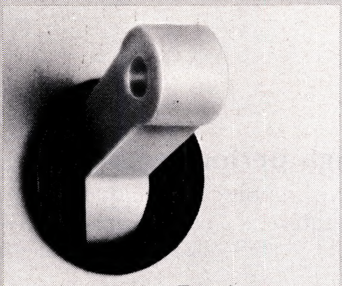
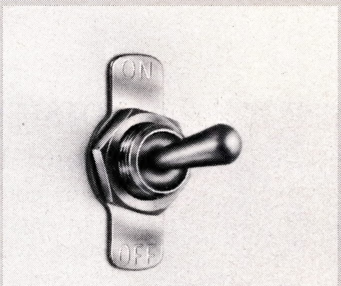
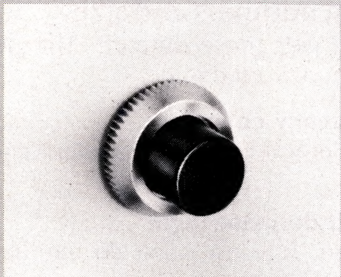


Toggle
Series JA, JB

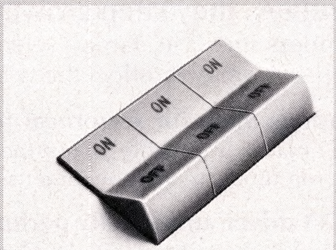
Rocker handle
Series JC



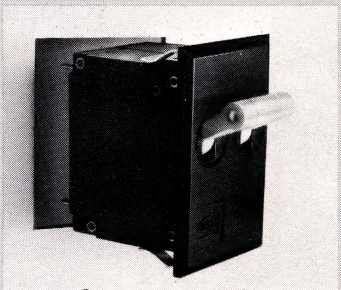
Environmentally sealed
Series JE



Pushbutton
Series JD



Multipole companion-trip
Series JA, JB, JC



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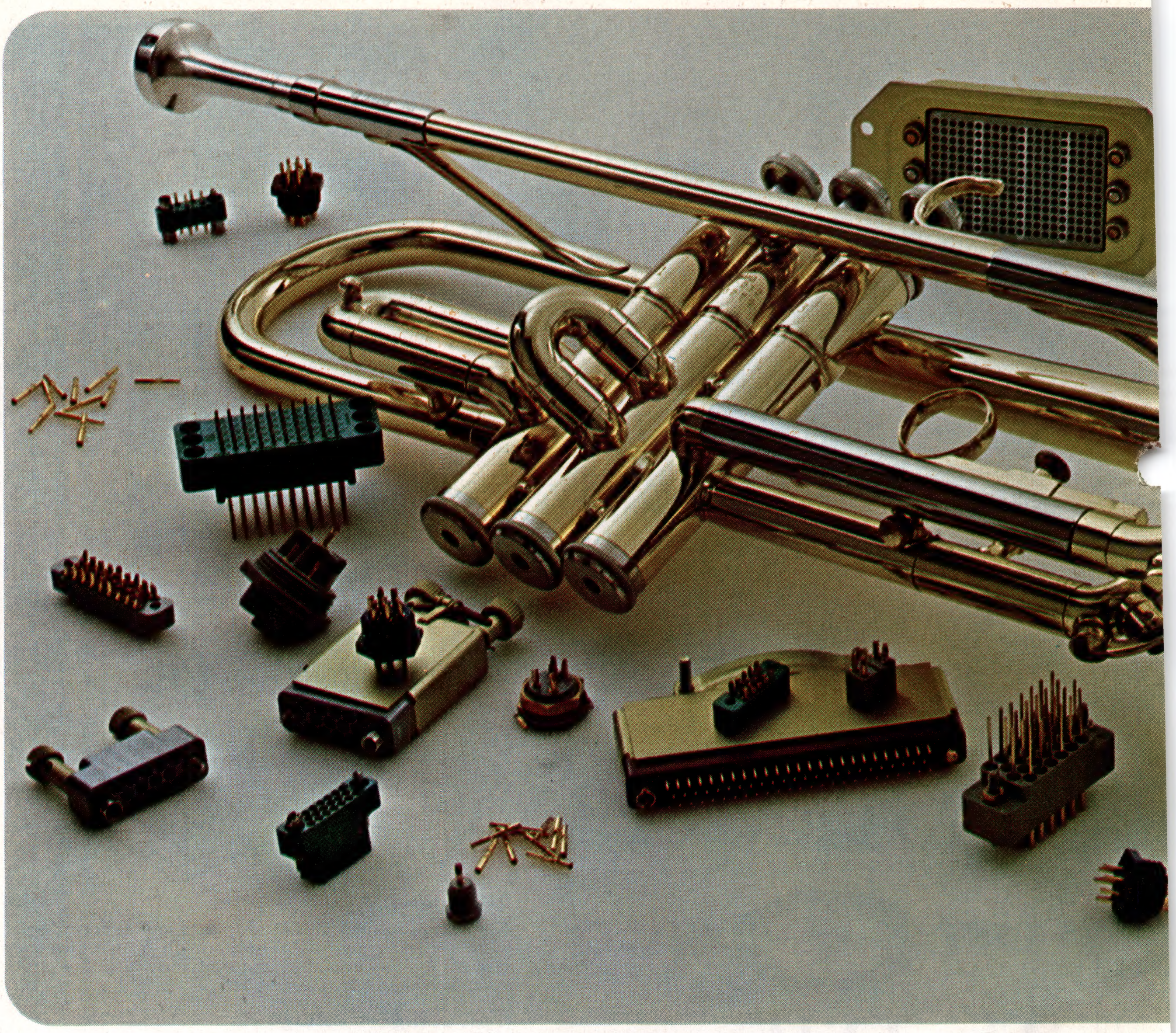

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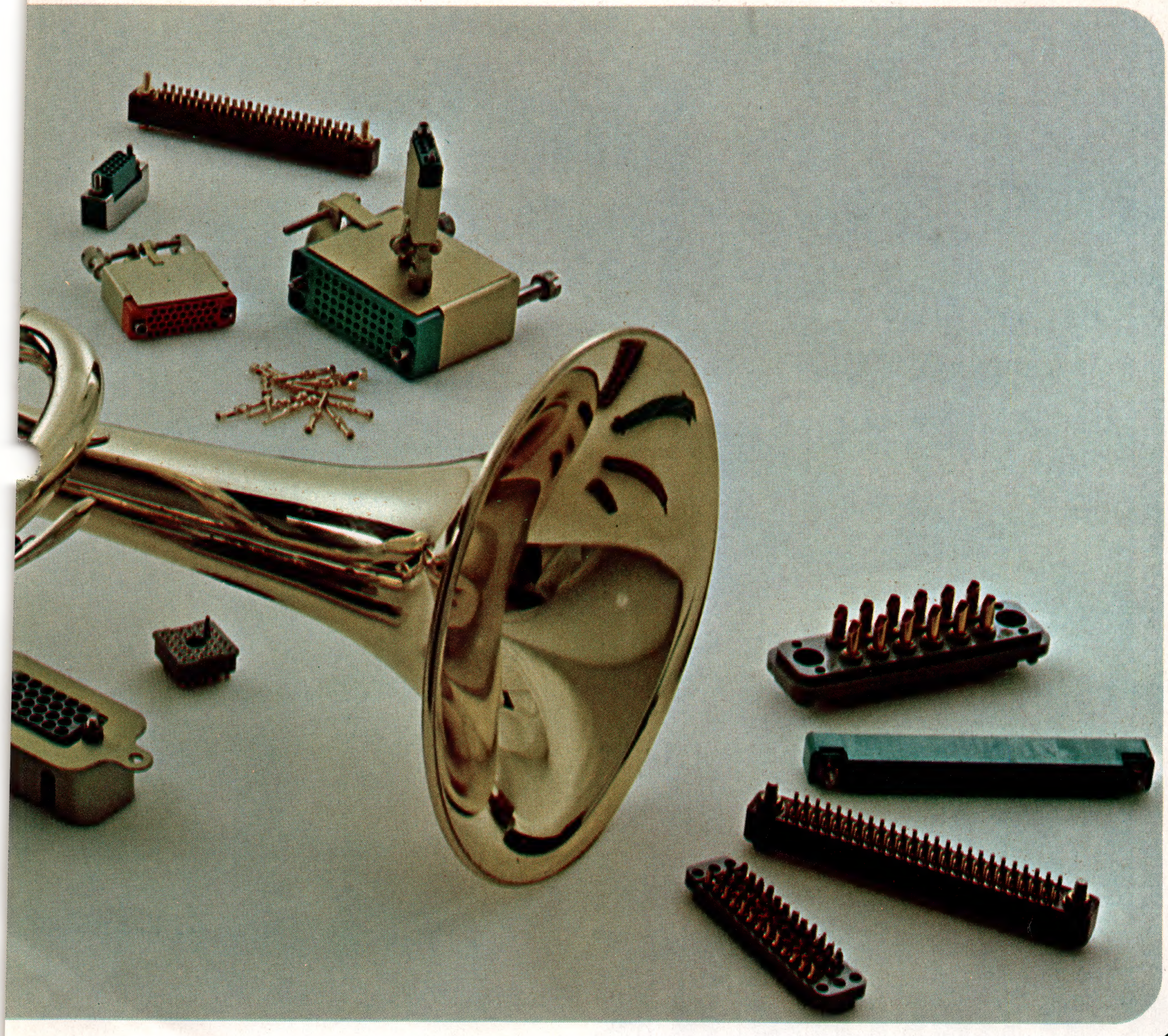

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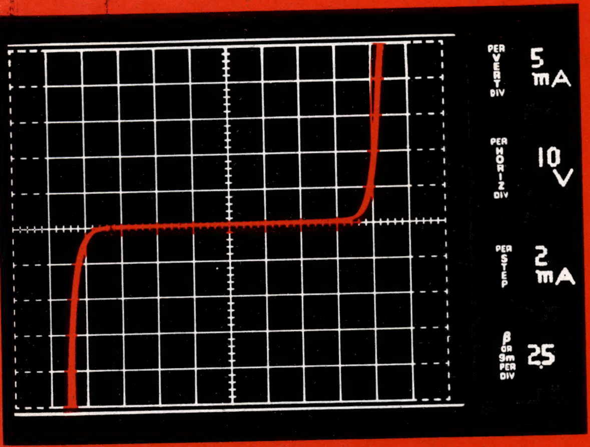
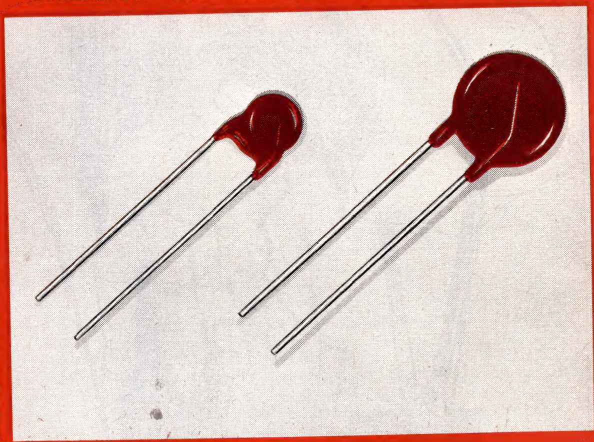


Actual photograph of V33ZA1 Characteristic



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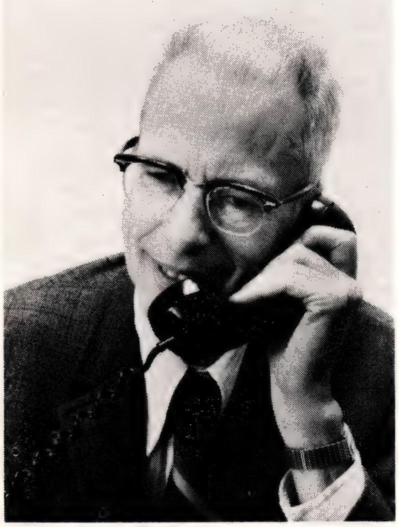


IC's: the good guys in white hats

Now that the nickel candy bar and 5¢ cigar have faded into oblivion—and 10¢ parking costs a quarter—let's give a lusty cheer for IC's. More than any other factor, MSI and LSI IC's have helped hold down the cost of electronic instruments and test equipment. They've been so effective that many of today's low-cost instruments actually sell for less than those available in pre-inflation times.

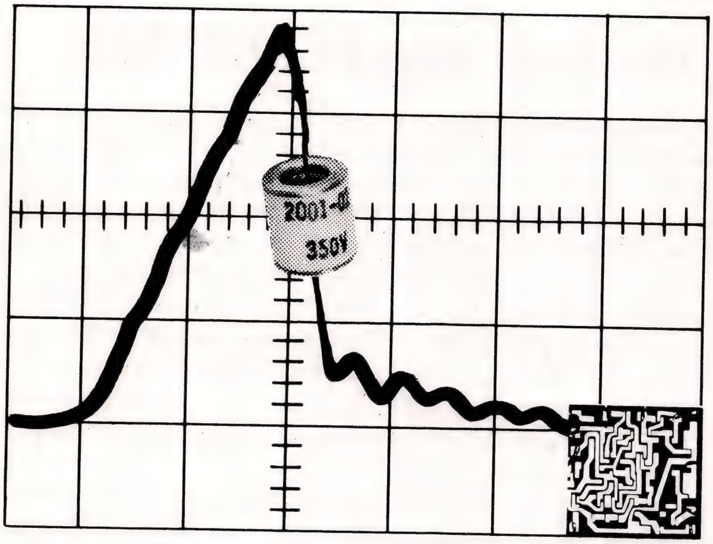
IC's should have credit for more than that, though. Only a few years ago, added complexity automatically meant added cost. Today, thanks to IC's, little if any of that relationship remains. Look at the simple 4-function pocket calculators for a good example. They're complex as can be, but priced less than a pair of shoes.

Dig into the reasons why you can plunk down $17.95 and walk away with one. High on the list will be the virtual elimination of wiring and soldering. If that calculator had been put together with discrete resistors, capacitors and semiconductors, you'd have had to move the decimal point over to make the price read around $1795. Not only that, but it probably would not have worked when first turned on, and the parts cost alone would have been a multiple of $17.95.

IC's thrive on very low power, which revives the practicality of battery powering for many classes of electronic instruments. Just in the last year or two we've seen battery-powered DVM's, scopes, counters, calculators and others. Portability with performance is a reality.

We really owe a lot to those MSI and LSI devices!

Earle Dilatush
Associate Editor



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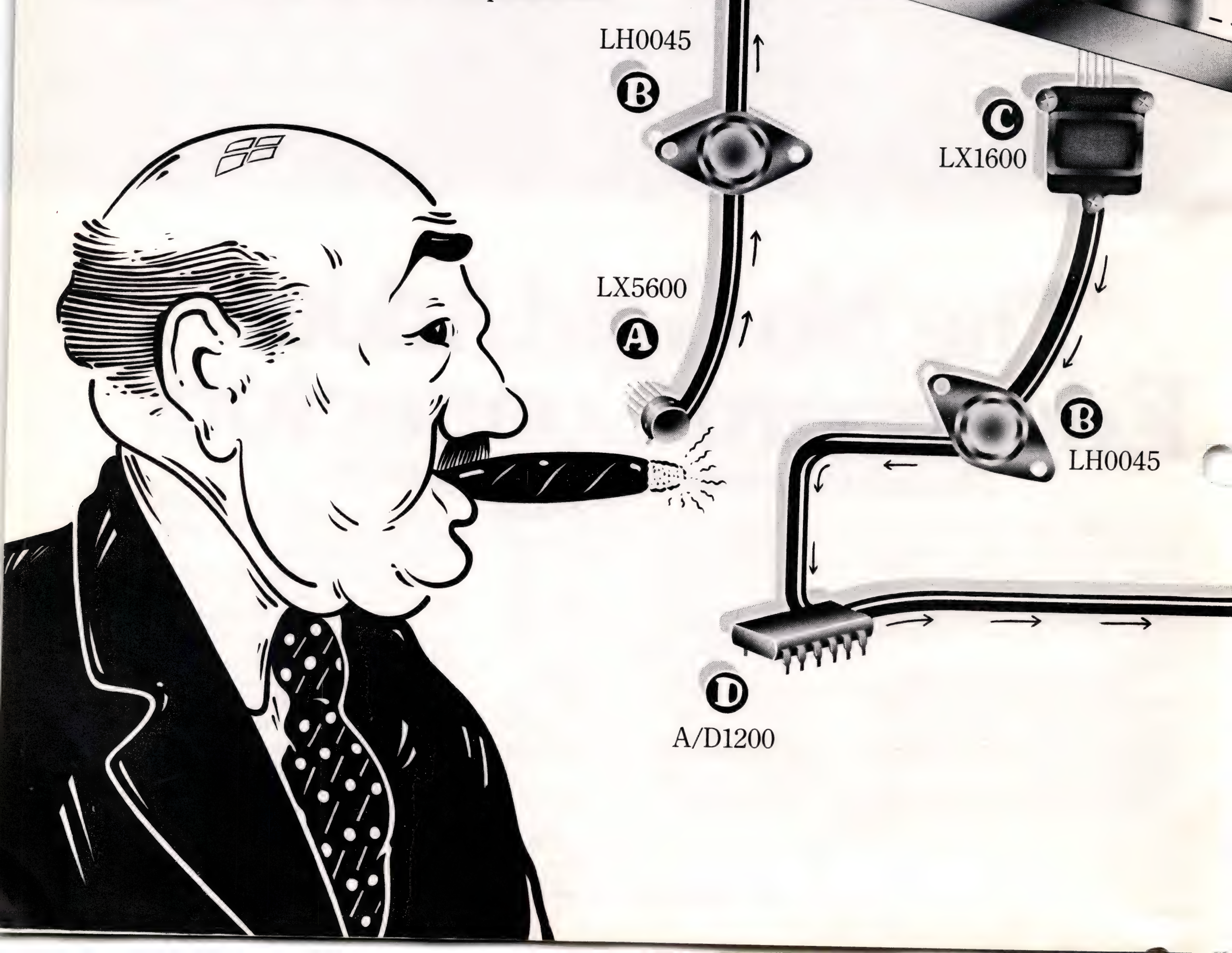
How National gets
of a falling

This is our temperature transducer Ⓐ that is activated by the heat of the cigar and transmits a signal by the 2-Wire Transmitter Ⓑ to the device that tips the steel ball off its perch, activating — as it rolls down the ramp causing a whoosh of air — the pressure transducer Ⓒ, which signal is transmitted again via the 2-Wire Transmitter Ⓑ to the A/D Converter Ⓓ which converts this analog signal to a digital signal which feeds into our IMP-16 microprocessor Ⓔ which is programmed to react to this particular input by activating a digital read-out Ⓕ which flashes a coded warning to the unsuspecting man, Ⓗ, and in case this warning isn't heeded, activating, after going through a D/A Converter Ⓓ, a device which pushes the man out of the way of the falling steel ball.

What's the point?

The fact that nowadays the



you out of the way steel ball.

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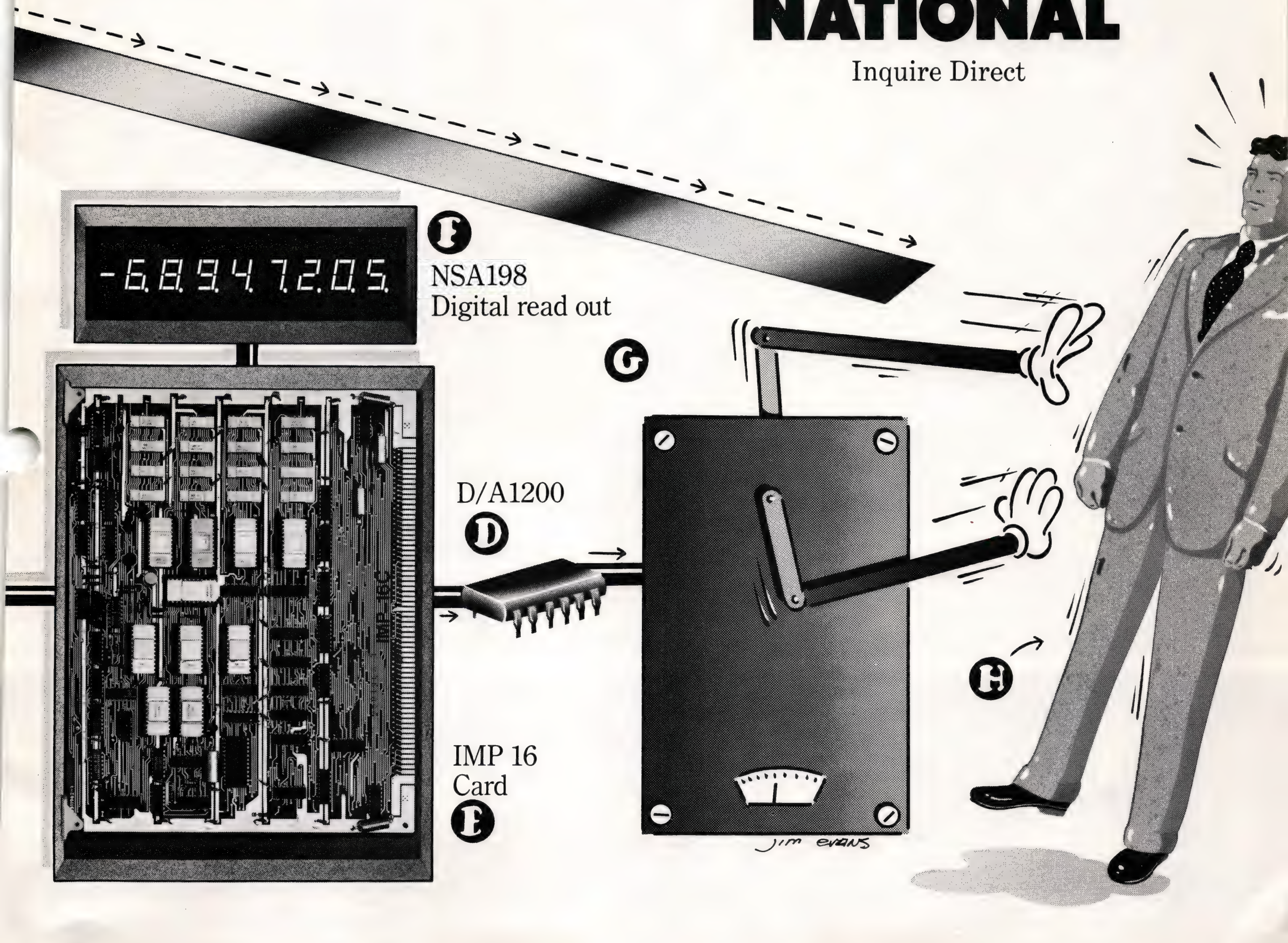

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Simplify variable and odd length SR applications

The MC14557 is a static, clocked, serial shift register which is easily programmed for any length between 1 and 64 bits. That means it can be used for variable digital delay lines and other cases where length must vary during system operation, as well as for the implementation of odd length registers.

Because serial data may be selected from either A or B inputs with a select input, recirculation is no problem for the MC14557. There is a clock enable input, too, to provide gating of the clock or negative edge clocking capability. And, the MC14557 has an asynchronous master reset. It's available in standard 16-pin plastic or ceramic dual in-line packages. The plastic (CP) version sells for $6.00 (1K to 4,999).

Think of the MC14557 as a liberator, and as one heck of a shift register.

MC14557 – one of eight SRs

Of course the MC14557 is just the newest among the McMOS* family's line-up of eight different shift registers ranging from the 4-bit MC14035 to the 128-bit MC14562.

Yes, Motorola's broad CMOS family offers more, and not just in shift registers. There's an excellent selection of the older simple circuits, the gates, flip-flops, etc., to go with the widest assortment of more contemporary MSI functions. In addition to the shift registers, the McMOS MSI line serves system logic needs with timers, counters, decoders, latches, buffers, data routers, arithmetic functions, analog multiplexers, and supplies more three-state CMOS logic than any other source. Then there are the ROMs, RAMs, and specialized functions like the priority encoder, parity tree, and dual Schmitt trigger. Motorola's McMOS is, in fact, the broadest line of CMOS available.

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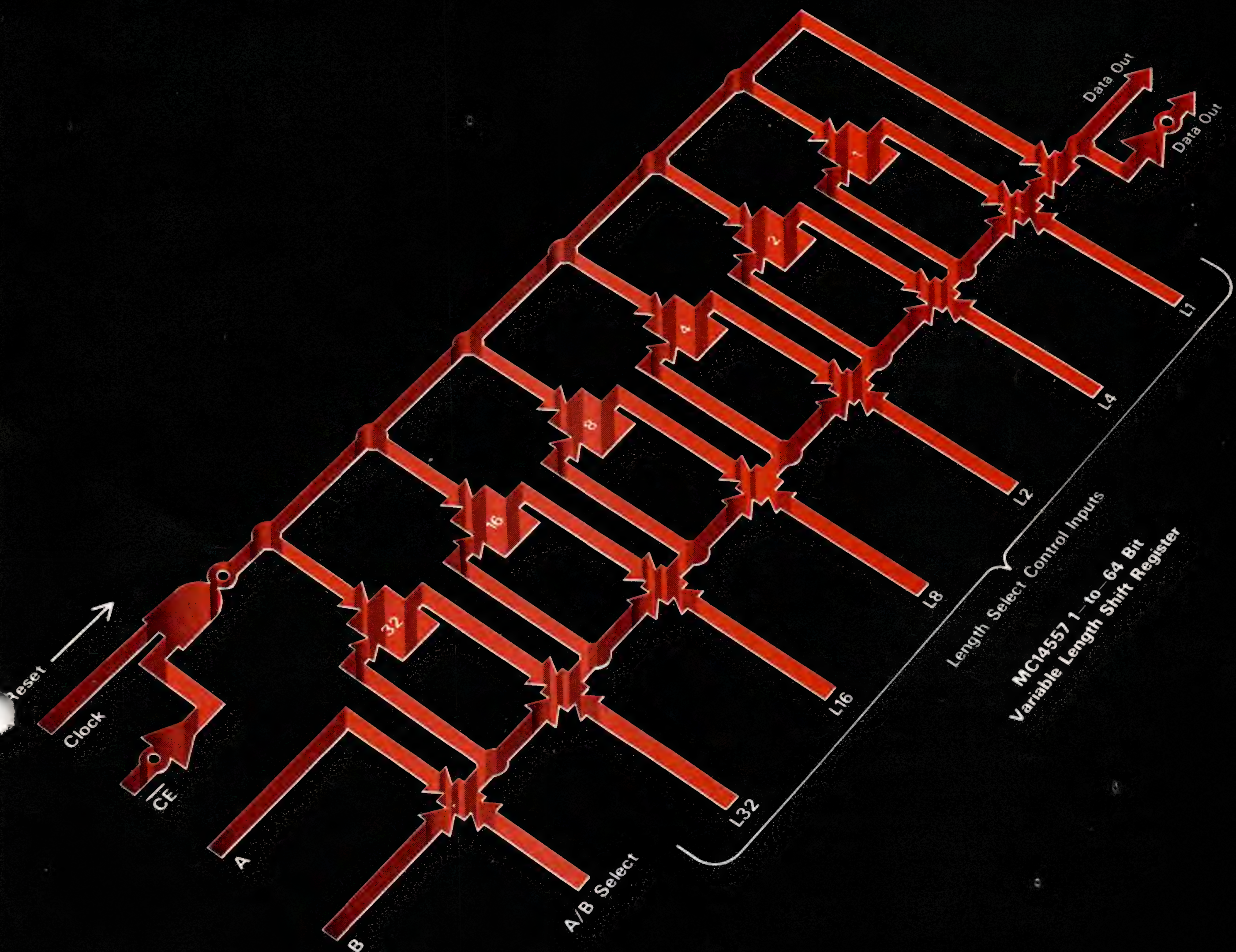
For additional technical information on the MC14557 variable length shift register, write to Motorola Semiconductor Products, Inc., P.O. Box 20912, Phoenix, Arizona 85036. For full technical and applications information, the McMOS Data Book and the McMOS Handbook are both on sale at franchised Motorola distributors.

For more information, Circle No. 18

the first variable length shift register.



MOTOROLA McMOS

–CMOS for contemporary systems

Color TV projection system achieves new high performance goals

Erwin Vodovoz, West Coast Editor

High brightness and resolution, precise color registration, large screen and long life can be attributed to Philco-Ford's color TV projection unit (TVPU). Advances in two main areas, CRT design and color registration techniques, made this system possible. It is the culmination of 10 years of work in large screen TV projectors by their Western Development Laboratories Division. Work on the color CRT alone took about 18 months.

Registration technique

If the heart of this system is the CRT, then the color registration circuits surely are the brains. **Fig. 1** shows the main units of interest. Three CRT's, one each for green, red and blue, comprise the system called a "Three Pack" (**Fig. 2**). A second system produces twice the picture brightness. Called the "Six Pack," it uses two CRT's for each color. The technique that makes possible the accurate color registration of the Three Pack

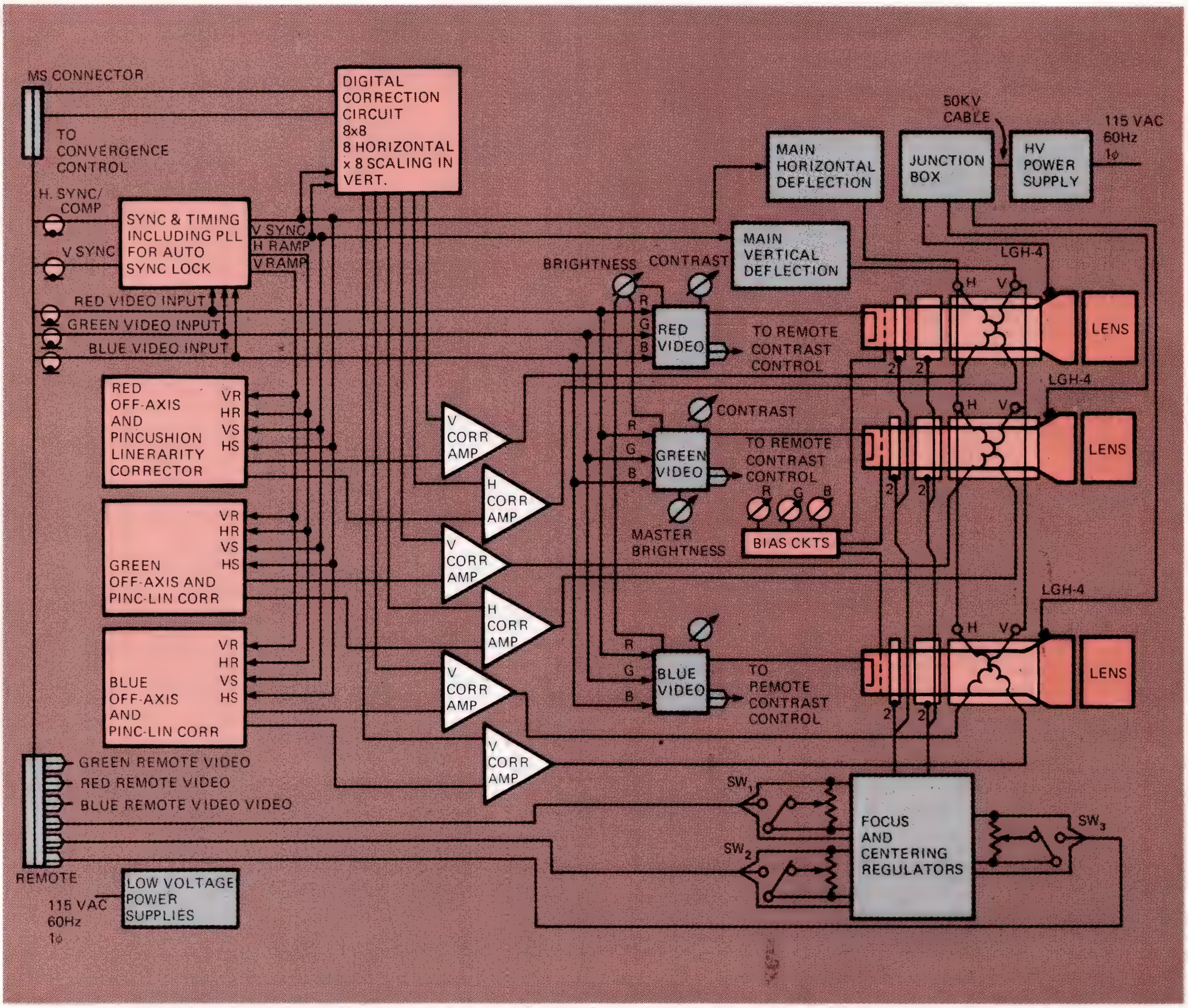


Fig. 1—Color projection system uses both digital and analog techniques to produce a high quality picture.

Fig. 2—"Three Pack" projector uses a vertical packaging technique to provide easy access for maintenance. The "Six-Pack" version is two Three Packs side by side allowing access to all units. Failure of one of the Three Packs in a Six Pack results in brightness reduced to one-half, not complete failure.

also allows ganging of units to make the Six Pack.

Some of the problems that had to be overcome to produce this high-quality, large-screen projection display were linearity; pin cushion, keystone and off-axis effects; differences in circuit components such as CRT's, lenses and deflection coils; and misalignment of the screen. These problems were corrected by a combination of analog and digital circuits.

Analog circuits take care of the pin-cushion, keystone and off-axis correction made necessary by the 13-in. separation between the CRT's.

Correct me if I'm wrong...

Keystone correction is accomplished by modulating the size of the horizontal sweep as a function of the vertical position on the raster (**Fig. 3**). The modulated ramp signal is then fed through a pin-cushion correction module. It, in turn, corrects the linearity and pin-cushion errors as a function of the horizontal and vertical positions on the raster. Corrected horizontal and vertical sweep signals, as obtained from the pin-cushion corrector, are next fed to the horizontal and vertical deflection systems.

The vertical tilt correction circuit, also shown in **Fig. 3** performs off-axis correction. A varying amplitude of the horizontal sweep is superimposed on the vertical ramp. This levels horizontal lines that are otherwise tilted vertically by the projector. The corrected vertical ramp is then fed through the pin-cushion circuits.

Key is digital correction

The uniqueness of this color system is mainly due to the digital correction generator (**Fig. 4**). This circuit compensates for all the other remaining errors between the three colors.

Final color registration is performed by partitioning the screen into 64 areas and displaying a crosshatch pattern using two colors at a time. A joystick superimposes the intersection of one crosshatch pattern over the second pattern wherever required. This procedure generates both the address and data commands necessary to produce the required color registration. The values are clocked out synchronously by the horizontal and vertical oscillators. These oscillators in turn are synchronized to the horizontal and vertical sync used to drive the deflection circuits.

The digitally-generated correction signals combine with the analog sweep signals to produce a color registration of better than 1/8 of a picture element.

Not without the CRT

Of course, none of the above would do any good if the necessary CRT was unavailable.

Having worked on the development of projection system CRT's for a long time, Philco-Ford is very confident that the life expectancy of these tubes is in excess of 2000 hrs. Most failures have been mechanical (tube cracking), not electrical.

Specifications of interest for the CRT shown in **Fig. 5** are max. accelerator voltage, 50,000V; average accelerator cur-

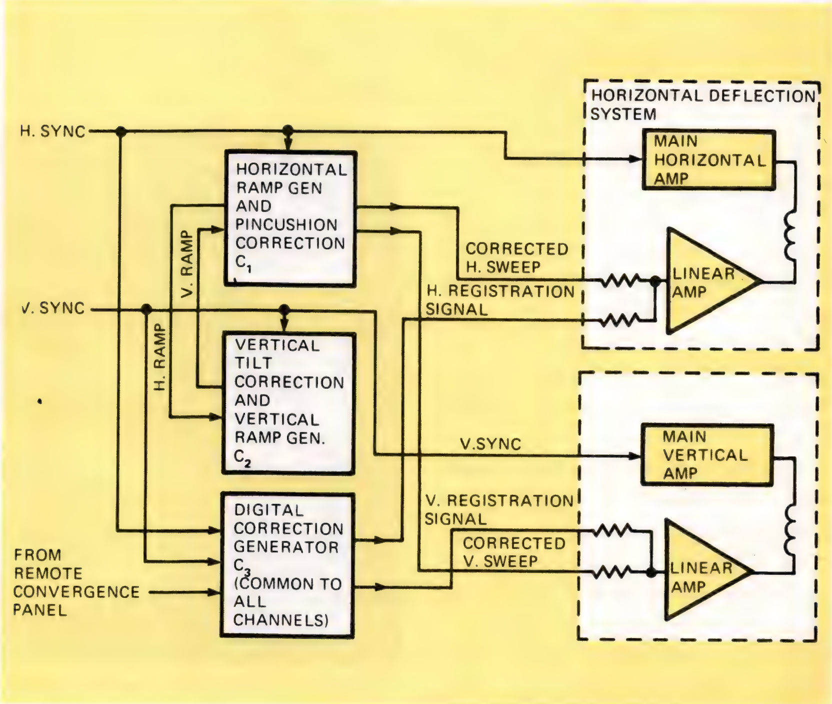


Fig. 3—Analog color registration circuits for one channel provide the coarse color adjustments for the system.

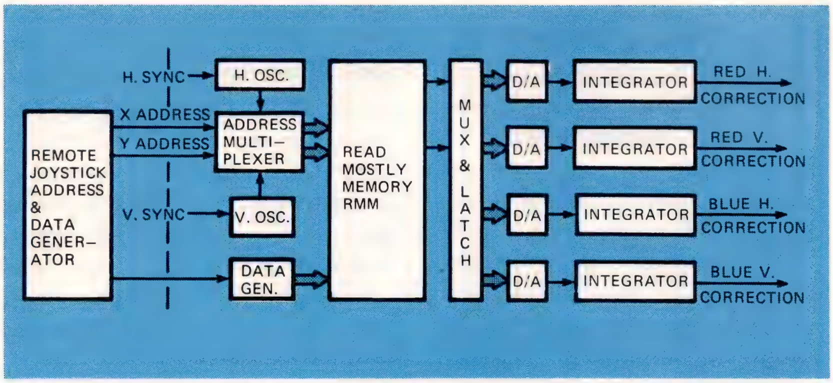


Fig. 4—Digital color correction circuits provide final fine adjustments needed for color registration. A correction voltage is generated for each X and Y location for 64 areas within the screen.

rent, 1 mA; useful screen diameter, 5.9 in.; focusing and deflection method, magnetic; and light output of 36,000 fL for green, 18,000 fL for red and 6000 fL for blue. Fortunately, the light output for the three colors is the amount required to produce a picture balanced in color to the human eye.

The lenses and circuits of this system are also noteworthy. Each lens has a 4×4-in. useful area and is rated at f = 0.88 or f = 1, depending on light requirements. Ultra-stable circuits (time and temperature) are used to insure good registration for 24 hrs. after adjustment with the joystick.

System highlights

What does all of the above mean for the TVPU? To start with, a system with resolution in excess of 1000 lines and brightness of 2400 lm max. for the Six Pack and 1200 lm max. for the Three Pack. A screen that measures 20 ft. diagonally for the Six Pack and 13 ft. for the Three Pack is based on the amount of light required on it. Also, the system's display may be a standard 525 line, 30 frame/sec interlaced picture or 60 frame/sec noninterlaced picture with more than 1000 lines. Finally, operating costs are expected to be lower than other large screen projection systems because of the long life of the CRT's. Thus, the manufacturer can claim a lower initial price. □

Why not use a 555 timer as an inexpensive power supply?

Why not, indeed! In our December 20, 1973 issue (p. 81), Maxwell Strange suggested this idea in his Design Award "IC timer makes transformerless power supply." His concept was simple, novel, practical and complete (both positive and negative versions were shown and a load regulation curve was given). Accordingly, you, our readers, voted it "Best of the Issue" and our editors subsequently voted it "Best of the Year" (1973).

To the victor go the spoils—in this case, a $1000 U.S. Savings Bond. Strangely enough (pun intended), Max also won the grand prize in the NSC/EDN Quad Linear contest. Thus Erwin Vodovoz, our West Coast Field Editor, had the privilege and pleasure of presenting him his bond at the Quad Linear awards banquet. A man who believes in the future, Max plans to invest the money in his children's education.

Could YOU use $1070?

Submit your Design Awards entry now! You could be our next Grand Prize winner!—*WP*

"I can't believe I won the WHOLE thing!" Or so Maxwell Strange (**right**) seems to be saying as he accepts his $1000 U.S. Savings Bond from Erwin Vodovoz, EDN's West Coast Field Editor. Max's Grand Prize Design Award appeared in EDN, December 20, 1973, p. 81.

Unique communications system holds promise as standard for the future

A live two-way television communications system, the first to be used on a continuing basis by US industry, has been installed by Dow Chemical USA. Employees headquartered in Midland, MI, have been able to conduct technical conferences, laboratory experiments, product business team meetings and management planning discussions with their Dow Freeport, TX, counterparts without ever leaving Midland.

Manpower conserved

Mobile color television equipment was designed by a TV consultant and installed by Telemation, Inc., of Salt Lake City, Utah. Included is a sophisticated sound system developed uniquely for Dow by Audio Services, Inc., of Detroit, MI.

From Dow Midland headquarters, the live program signal is microwaved to Saginaw, MI, where it is sent over an AT&T network backup channel to Houston, TX. From Houston, the signal is microwaved to the Freeport broadcast facility. The portable equipment at Freeport can be moved to a studio in the Houston Dow Center in case transmissions are needed there. Usage charges for the 1400 mile transmission are approximately $2000/hr.

Earle B. Barnes, company president, conceived the project as a possible means to reduce travel between the two locations. In 1973, more than 3500 round trips were made between the plants at a cost of $700,000. In addition, a minimum of 15 hours round trip results in over 52,000 man-hours spent traveling. That's a total travel expense tag of $1.4 million for 1973.

"But the dollar costs are secondary," said Barnes. "The real key is the man-hours spent traveling and the physical wear and tear. For a one hour conference at either location, about two days are spent traveling."

System expansion likely

The project was originally planned for technical conferences between research groups at each facility. But initial samplings have shown enthusiastic response for other types of application. Interest in testing the system has spread to marketing and product groups,

We blended our extensive fixed resistor knowhow with 15 years of cermet experience to produce an outstanding cermet film resistor. And we've developed unique manufacturing techniques that let us provide consistent quality.

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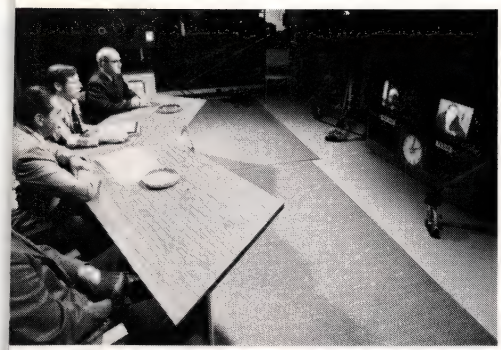


Dow USA employees participate in new telecommunications system that allows simultaneous communications between Midland, MI, and Freeport, TX.

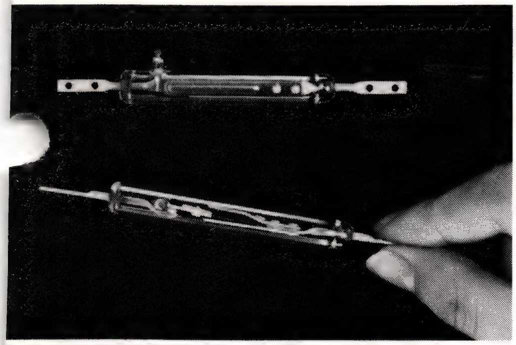
technical service and development and task forces dealing with industrial problems.

Charles Alstad, Manager of Information Services, and project coordinator, explained the positive responses. "Instead of sending one or two persons to Midland or Freeport to bring back information, everyone connected with the project can participate on a personal basis. With this system, more people become directly involved—each studio can hold as many as 40 people."

"This medium obviously will never replace face-to-face meetings," said Barnes. "It isn't intended to. But it can help supplement personal contacts when traveling back and forth is not practical. If we can use this medium to help accomplish our goals, then the price is well worth it."—*TO*

High-power/high-voltage reed switches now handle to 3 kVA or 6 kV

Most people think of reed switches as low-power devices, as indeed the majority of them are. Now, in a program aimed only at the Japanese market, Matsushita Electric has announced two lines of very heavy-duty units. One, rated at



Compact power reed switches (top one rated for 5A at up to 500V and lower one for up to 6 kV at 0.5A) open up new areas of practical usage.

2.5 kVA, handles up to 5A at 500V or lower, and the other with 3 kVA rating handles up to 6000V at 0.5A.

Conventionally, both air and mercury switches have served in high-voltage applications. Both have limitations. The air switch is sensitive to dust and gas, while the mercury switch requires special care of the mercury and its disposal after use. Power reed switches pose fewer problems, since the elements are hermetically sealed in a glass container. Hence dust and gas cannot cause malfunctioning, mercury hazards are eliminated, and the new units are safe to use in areas that require explosion-proof design.

Compact dimensions remain, in spite of the impressive power ratings. Case size is only 8.7 mm in dia. × 56 to 66 mm long (approx. 1/4-in.×2-1/4 to 2-2/3-in.), and weight runs from 7.7 to 8.9 gm. As noted previously, Matsushita's current plans call for development and commercialization of their products only in Japan.—*ED*

These new Unitrode 300V power darlingtons

perform like this

I_C A	V_{CEO}† V	h_{FE}	$V_{CE\,(sat)}$ V	Type No.	Package (Modified)	Polarity	Power Dissipation 100°C Case W
2	300	1000 @ $I_c = 1A$	1.5* @ 2A	U2T103	TO-33	NPN	5
2	300	1000 @ $I_c = 1A$	1.5* @ 2A	U2T203	TO-66	NPN	20
5	300	1000 @ $I_c = 3A$	1.5* @ 5A	U2T303	TO-3	NPN	50

†V_{CEO} measured at 10 mA   *Forced gain = 100

and...

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UNITRODE

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EDN/NSC quad linear winners receive an unexpected bonus

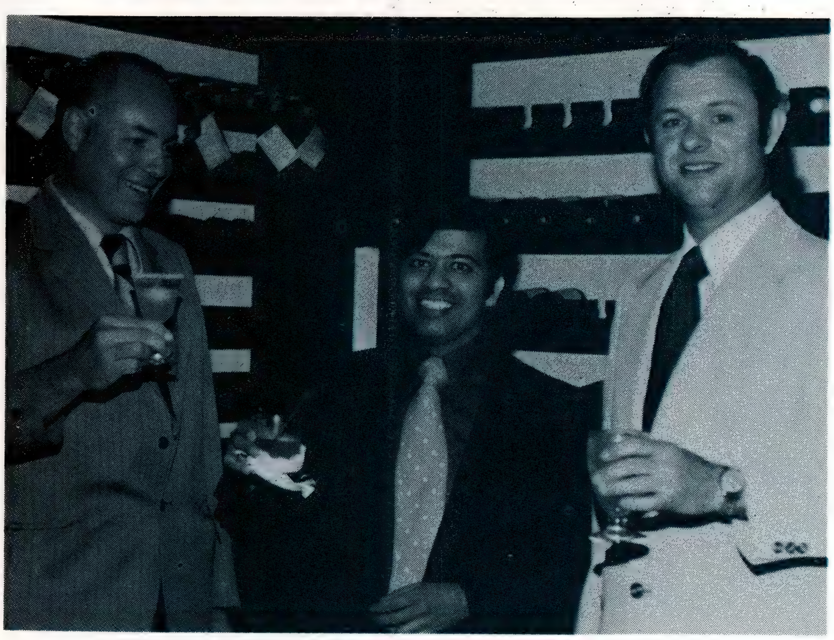
Max Strange, Vic Godbole and Bill Renison were caught by surprise. Nevertheless, they accepted National Semiconductor's invitation for an all expense-paid trip to California that included a VIP tour of NSC's facilities and an awards banquet honoring their achievements.

The three winners were met at the airport on Thursday, Aug. 15 and chauffeured to their hotel to prepare for Friday's activities. These involved a lengthy meeting with Tom Fredrickson, the "Father of Quad" and, officially, Manager of Design Linear Quad operations, and a comprehensive tour of the plant. In what was definitely a high point of their visit, the men viewed the actual production of a semiconductor from the cutting of the silicon to the packaging of a circuit. They were amazed at the complexity of operation vs. the semi's relatively inexpensive cost.

After a little "R and R," Max, Vic and Bill proceeded to Paulo's in the Prune Yard, a fine old-world Italian restaurant and site of the 8-course awards dinner. Here Gene Carter, Director of Marketing for NSC's semiconductor division, and Erwin Vodovoz, EDN's West Coast Editor, thanked the men for their contribution and their interest in quad's. Max Strange, grand prize recipient, spoke for all three winners when he thanked the sponsors for an "experience of a lifetime."

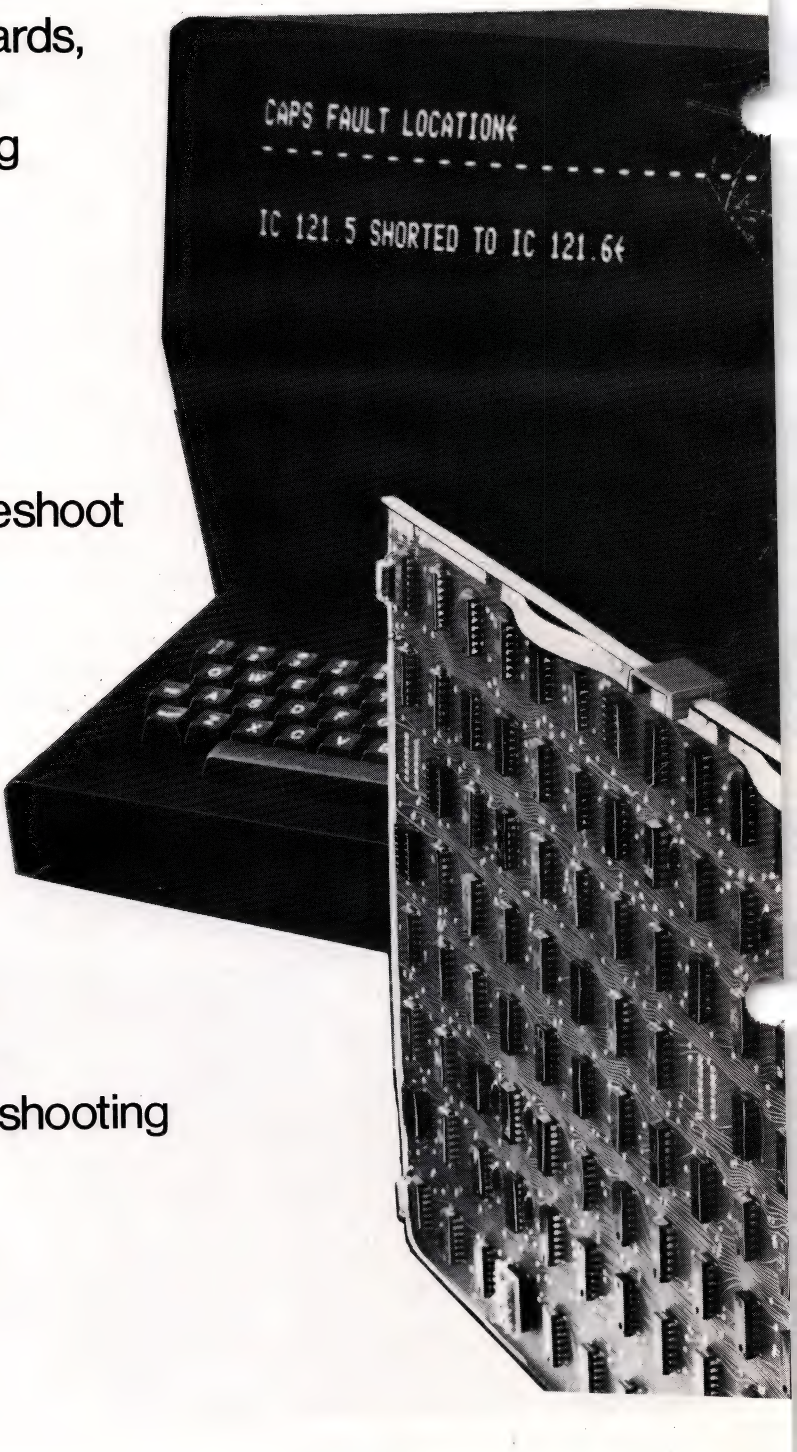
The last, but not the least, of the festivities took place Saturday when a car was placed at the men's disposal for a tour of San Francisco's Bay area. Thus ended an enjoyable three days for all participants.

Both the winners and NSC gained much from this interaction. While Max, Vic and Bill were impressed with National Semiconductor's expertise, good will and generosity, NSC, in turn, was very favorably impressed with them. They found the men excellent engineers—extremely knowledgable, capable and most interesting.—*CL*



"I'll drink to that!" Max Strange, Vic Godbole and Bill Renison, EDN/NSC quad linear contest winners, toast the town—and their hosts—at the awards banquet.

Five points to keep in Logic-Circuit



1. When testing complex boards, you spend most of a tester's available time troubleshooting defective boards.

2. Troubleshooting can be time-consuming and costly.

3. Not all test systems troubleshoot equally well.

4. Software is the least understood and the most important part of any test system.

5. The system that provides the best hardware/software integration minimizes troubleshooting time and expense.

mind when evaluating Testers...

It is the last point on the facing page that separates the GR1792 Logic Test System, with its CAPS software package, from all other logic-circuit testers. Among other things, CAPS removes the human element from troubleshooting as much as possible. In fact, it actually makes troubleshooting fun!

CAPS stands for Computer-Aided Programming (and fault diagnostic) Software, and it features two different troubleshooting techniques. One technique, automatic fault location (AFL)*, literally removes the operator from the troubleshooting procedure. Within seconds after a fail signal appears, the CRT displays a series of messages that resolve not only *what* the fault is but *where* it is located. With the second technique the operator uses a computer-guided probe, with CAPS guiding the operator through the logic and leading him quickly to the fault.

No single troubleshooting technique can find all possible failures on every type of board design. GR is the only manufacturer that provides *both* on-line fault simulation and the probe, and our dual techniques offer more time-saving troubleshooting versatility than any other system.

There is much more to tell about the GR1792 and CAPS than space permits here. To learn more, write for a copy of our new 1792 Data Bulletin that gives you insight into logic-circuit testers in general and the GR1792 in particular.

With over 200-logic-circuit test systems shipped during the past few years, GR has developed an LCT expertise in both hardware and software that is second to none. If you are considering investing in a logic-circuit test system, or several systems, be sure to learn what GR can do for you. We think you'll be pleasantly surprised . . . like so many others.

*Patent applied for

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DESIGN FEATURES

IC logic families: they keep growing in numbers and size

As their numbers increase, family selection gets more difficult. The performance of your system will reflect the wisdom of your choice.

Tom Ormond, Associate Editor

If you're about to come face to face with the problem of selecting a logic family to implement your design, we wish you luck. Today's designer faces a staggering array of families from which to make a choice. Basically, there's DTL, TTL, ECL and MOS. In addition, you have Schottky, and low power, and high speed, and high noise immunity, and...

The list of established families is certainly varied enough to make a choice complicated. Add to it the number of newly emerging technologies that hold promise as families of the future, and you really define the problem. Or do you?

Family existence is not really indicative of family health. Many of today's logic families have had limited acceptance. Consequently, they have evidenced little, if any, market impact. Since selection is complicated enough without the addition of these stagnant families, a reduction in the number of choices is mandated.

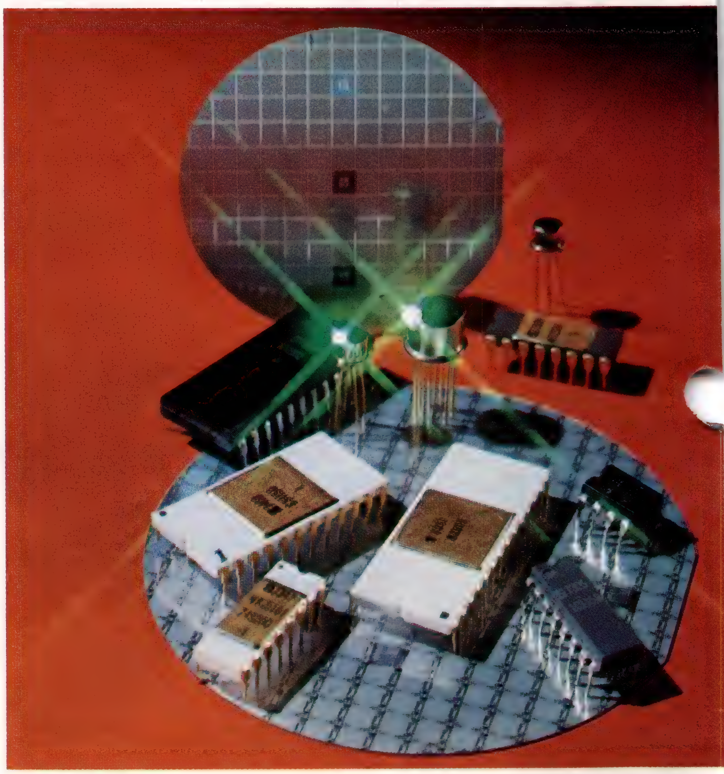
Realistically speaking, just about any problem facing today's logic designer can be solved by use of one, or more, of four families or technologies: standard TTL, Schottky TTL, ECL or MOS. If you think this is a rather drastic reduction or simplification, it's not. These four families provide all the solution capability you're going to need today, and tomorrow.

The king still lives

For the past three or four years, articles extolling the virtues of this or that family have either implied, or explicitly stated, that it was certain to be the one that was going to replace TTL as the leading logic family. And yet, as we approach the end of 1974, TTL is still the top line.

54/74 series is today's standard TTL family. It is, by far, the largest family in existence. A testament to it's vitality is its continued growth. In this year alone, over 40 new types have been added to bring the family size to well over 200 functions. Growth areas are at the MSI complexity level, an indication of family maturity.

Just about every IC manufacturer now offers the 54/74 family as part of its line. It is, in essence, the "bread and butter" family, both from the point of sales and usage. It has achieved and maintained this status despite, what are by modern standards, rather bland characteristics. With power dissipation of 10 mW/gate, and propagation delays of 10 nsec, the family should be dying. On the contrary, 54/74 remains the industry workhorse. Usage in video games, industrial controls, computers and computer



Logic, logic everywhere, how do you make your choice? Some manufacturers, such as Signetics, offer such broad product lines, it makes it very complicated.

peripherals, data terminals, telephone switching systems and electronic calculators reflect the breadth of its applications base.

Historically, new logic families have duplicated the functionality of the 54/74 family in their growth years. Based on proven capability and designer familiarity with 54/74, this approach is understandable. Of greater importance, however, is the size of the TTL market. In 1974, the TTL market reached a sales level of $500 million. To reach the top of the heap, newer families must be capable of offering comparable performance at equal or lower prices. Can any of the challengers really measure up to the test?

Schottky holds great promise

Schottky technology embraces two unique families: high speed and low power. Of the two, low-power Schottky seems to have the brighter future.

When it comes to speed, Schottky cannot, and does not, compete with ECL. Its niche seems to be basically one of upgrading systems already using standard TTL. Instrumentation, minicomputers, high-speed intelligent terminals and small communications systems are some of the historical TTL areas where 54/74S can dominate. Note that this represents a rather limited market area in relation to the scope of the TTL market. Without volume, 54/74S prices can never approach those of the 54/74 family, and the heavy investment necessary for functional expansion does not seem likely for such a narrow marketplace.

On the other hand, low-power Schottky looks exceptionally good as the family of the future. 54/74LS matches all the characteristics of standard TTL with only one fifth the power dissipation. The entire TTL market, therefore, is easily within its grasp. Complete systems redesigns can be accomplished by simple drop-in substitution. This compatibility is an asset that cannot be discounted. Have you considered it yet?

System improvement simplified

Low-power Schottky represents the latest development in TTL technology. With 9.5 nsec delay, 2 mW dissipation and 45 MHz flip-flop toggle rates, it offers 54/74 performance at one fifth the power. Speed-power characteristics of 54/74LS (**Fig. 1**) are such that many systems previously designed with a combination of 54/74 and 54/74L can be immediately upgraded with 54/74LS. Introducing 54/74LS logic into 54/74 type system designs makes it possible to reduce the size and cost of the power supply, with attendant reductions in heat dissipation and operating costs. In today's energy-conscious design world, such factors assume paramount importance.

A very compatible family

Low-power Schottky has basically the same input and output voltage levels as standard TTL. Drive capability is sufficient to interface with other TTL families in most applications without the need for buffer circuits. Its low input current requirements make it an ideal interface between TTL-compatible MOS devices and other systems. In addition, the high output current capability of 54/74LS enables it to drive a wide range of capacitive loads with minimum effect on device performance. This low-impedance output characteristic also allows low-power Schottky to drive reasonably long lines (up to 36 inches) without the need for terminated controlled impedance lines.

LS devices display transfer characteristics similar to standard TTL, and meet all the worst case conditions. Propagation delays are identical on turn-off and faster on turn-on. Edge speed is generally slower in LS than standard, but this is an asset. It creates fewer problems when it comes to crosstalk and power supply noise. Moreover, since 54/74LS switches only 25% of the current of standard TTL, current spiking problems are also greatly reduced.

What's the cost of power?

TTL technology has now reached the level where maximum circuit complexity is often limited by package power capabilities. When 54/74LS is substituted for standard TTL, circuit complexities can increase by a factor of five without exceeding package power limitations. This, alone, should make system designers take notice.

Low-power Schottky's reduced power can also have a significant impact on component reliability in a system. For example, if one compares the reliability of a typical MSI function in a system with an operating ambient temperature of 55°C, a

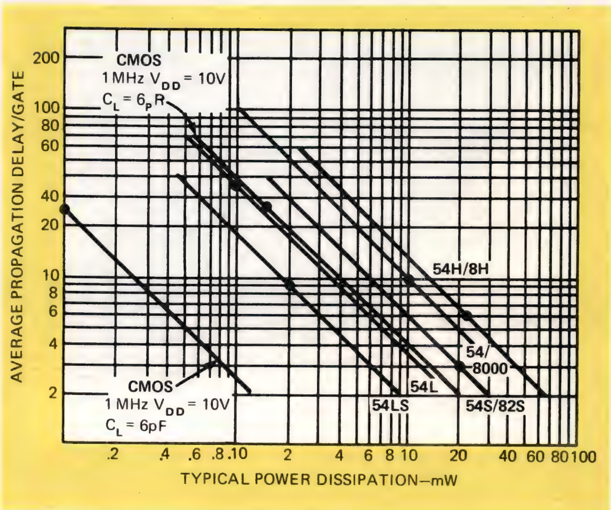


Fig. 1—Low-power Schottky's speed-power product allows for immediate upgrading of standard TTL systems.

four times improvement in component failure rate can result from the lower junction temperature of a low-power Schottky function versus a standard 54/74 function.

In comparing the cost of designing a system with a particular logic family, examine the total cost, including reductions in manufacturing costs. They may offset the higher price of a particular family. Although standard TTL is the lowest priced family available today (**Fig. 2**) 54/74LS is closing the gap fast. By 1975, low-power Schottky will be within 10% of standard 54/74 and will be a more cost effective form of logic for future designs.

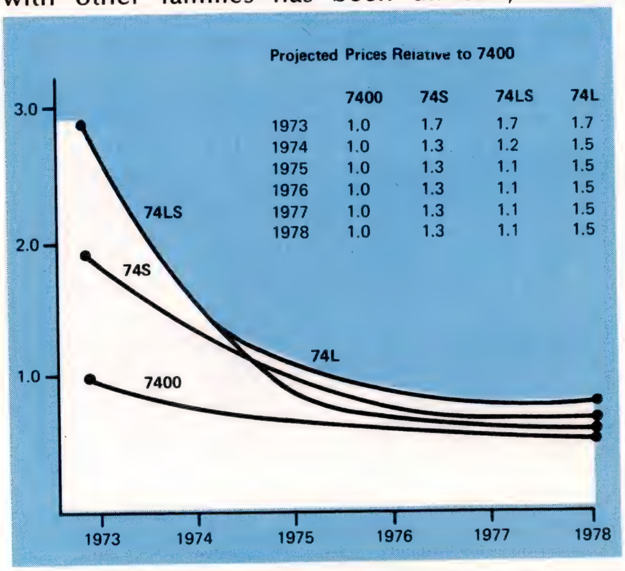
When all system considerations are evaluated, low-power Schottky can also compete with CMOS. For example, at relatively moderate speeds (on the order of 1 MHz), 54/74LS actually consumes less power than CMOS.

Let's look into the future

High circuit density, high speed and low power make 54/74LS a natural choice for high-performance bipolar LSI designs. Family growth will concentrate on duplication of the standard TTL line. Realistic projections indicate a family size on the order of 80% of standard TTL. Its compatibility opens up the entire TTL field for low-power Schottky. With the TTL market approaching two billion units shipped in 1974, the future for 54/74LS looks bright indeed.

It's not all TTL

Emitter coupled logic (ECL) has historically been the high-speed mainframe computer logic. It still dominates this field. Yet an asset can also be a liability. In this case ECL has been limited, in the past, by its speed. It's so fast that interfacing with other families has been difficult, if not



	7400	74S	74LS	74L
1973	1.0	1.7	1.7	1.7
1974	1.0	1.3	1.2	1.5
1975	1.0	1.3	1.1	1.5
1976	1.0	1.3	1.1	1.5
1977	1.0	1.3	1.1	1.5
1978	1.0	1.3	1.1	1.5

Fig. 2—As its price comes down, low-power Schottky's appeal goes up.

impossible. For this reason, systems requiring the speed of ECL in any particular socket usually wound up being ECL throughout.

Has ECL overcome this interface problem? Yes! No longer is it restricted to super speed applications. As the family functionality has broadened, so have its applications.

Lower your system costs with ECL

ECL has been an accepted logic form since the early '60's. Older ECL logic forms were noted for their high speed. But this speed was achieved at the expense of power, high cost and relatively difficult use. In 1971, Motorola introduced series 10,000, a family that overcame all the drawbacks of early ECL forms. Series 10,000 emerged as an answer, and attractive alternative, to costly custom programs previously used by mainframe computer manufacturers. In addition to the initial thrust into the large mainframe computer market, ECL 10,000 has made major inroads in applications for semiconductor test systems, add-on memories, minicomputers and telecommunications equipment.

ECL market requirements have grown (**Fig. 3**) from $20 million in 1971, to $65 million in 1974. Projections in 1976 for world-wide shipments of ECL are $150 million. **Fig. 3** also shows a significant shift in the composition of the ECL marketplace. Although computer mainframe applications dominated in 1971, they will occupy only 45% of the market in 1976 while peripherals and minicomputers will grow to 20% of the total. Instrumentation will maintain a significant share also, while telecommunications and digital communications of all kinds will increase to a significant 8% of the total market.

It offers more than speed

Series 10,000 has caught on in these historically non-ECL markets because it offers a broad range of useful complex functions, less power consumption, increased ease of use, low cost and dependable alternate sourcing. The family has grown to 85 functions, ranging from simple gates to complex memories. Gate costs have come down into the 30 to 40¢ range and four manufacturers now source the family. However, speed is still an important part of ECL's game.

The superior speed of ECL 10,000 has made it a natural selection for applications where earlier saturated forms of digital logic couldn't quite meet system requirements. Examples include minicomputers used to process signals in excess of 20 MHz, and equipment performing scientific manipulation of incoming data with fast Fourier transforms. ECL not only meets the speed re-

TABLE 1
DOMINANT CMOS APPLICATIONS

TIME KEEPING	Electronic Watches, Clocks, Control Timers
AUTOMOBILES	Auto clocks, Seat Belts, Controls for Pollution & Drive Train
INDUSTRIAL CONTROLS	Process Control Equipment for: Mills, Refineries, Printers
COMPUTER	Peripherals, Communication Buffer, Scratch Pad Memories
TELEPHONE	Tone Synthesizing and Detection, Cross-Points, Dialers
MEDICAL	Heart Pacers, Fluid Analyzers, Patient Monitoring
COMMUNICATION	RF Digital Tuning, CATV Converters, Pocket Pagers
MILITARY	Fuzes, Airborne Computers, ECM Equipment
SATELLITES	Data Acquisition, Low Power Consumption Logic
MISCELLANEOUS	Utility Meter Reading, Traffic Controllers

quirements of these applications; it also offers new design flexibility. One ECL user found that by processing data in serial fashion, his equipment could perform at the same level as an alternate TTL-S approach. At the same time, he lowered the cost of his system by nearly 20%, and used 23% fewer modules with 23% less power.

Add-on memory requirements, taking advantage of the increased performance of semiconductor memories, dictate the use of ECL 10,000 for control and I/O circuitry, as well as the memory protect function. By advantageous application of ECL, an efficient trade-off may be achieved between memory-chip cost and system speed. In other words, a slower, lower cost memory, when combined with ECL control and I/O circuitry, yields the best system cost performance ratio.

Keep it quiet!

ECL is being used in all types of instruments from counters and signal generators, to scopes and medical surveillance equipment systems. One new ECL use is intelligent instruments: systems that combine measuring ability with computing capability. The most complex of such instruments are integrated-circuit test systems. The slow ramp rates and balanced outputs of ECL circuits provide the lowest noise digital logic circuit available, regardless of speed. Low-noise generation and controlled signal integrity are of utmost importance to test systems for greatly improved resolution, accuracy and dependability.

As ECL technology has become more efficient, the level of integration has increased, and increased density brings benefits (**Fig. 4**). While power dissipation for simple gates (10101) is 25 mW/gate, more complex functions like a multiplier (10183) have a power consumption as low as 5 mW/functional gate.

A look at ECL's future

As ECL production volumes continue to increase in the ECL marketplace, improved production efficiency will permit additional cost savings to be passed on to the consumer. The trend to lower power LSI, as shown in **Fig. 4**, will also continue as new higher density products find their way to the market. ECL shows virtually no physical limitation to circuit density. Current products now feature 100 gates, and future trends indicate chips exceeding 200 gates.

Products soon to be introduced include such state of the art items as a 1.2 GHz divide-by-10 counter, picosecond logic functions, high bandwidth logic for instrumentation and communications applications and programmable ROM's.

ECL will continue to find broad use in systems requiring all-out performance. More importantly, it may be used to reduce parts count. A significant new direction has emerged for ECL as designers and managers realize the dollar value that high-speed logic adds to their equipment. ECL has the potential for reducing parts count and system cost by modifying architecture to achieve the same or better performance from smaller, less expensive systems.

MOS technologies mushroom

For many years, CMOS was the 4000 Series. First introduced in 1968 by RCA, many companies have, and still do, second source this series. However, some of these companies are now developing their own lines. The leading alterna-

TABLE 2
COMPARISON OF FAMILY CHARACTERISTICS

	CMOS	TTL
Low Quiescent Power (per gate)	10 Nanowatts	100 Microwatts (only for low power TTL)
Wide Operating Voltage Range	Lower–3V Upper–15–18V	4.5–5.5V
High Noise Immunity	30–45%	8%
High Input Impedance (Typically)	10^{12} Ohms	4000 Ohms ("O" State)
Temperature Stability (–55 + 125°C) (Voltage Switching Transf. Characteristics)	±1.5%	±20%
Power Supply Symmetry	Identical Performance (0 → +15V = –15V → 0)	Optimum Only with 0 → +5V Supply
Balanced Output Drive	Outputs—Active Complimentary Transistors	Output Impedance Highly Unbalanced due to Single Ended Drive
Delay	25 nsec	6–10 nsec
Speed	10 MHz	30–50 MHz
Fan–Out	50	10–15
Cost/Gate (min)	30–35¢	15–20¢

tive to the 4000 Series is the 54/74C family introduced by National. Both families use standard metal-gate fabrication techniques and silicon substrates. Members of the 54/74C family feature identical pinouts to their 54/74L counterparts.

Other alternatives to the leading series stick with the 4000 Series pinouts. The F34000 Series from Fairchild offers increased output drive capability and improved circuit density over the 4000 family. Twofold increase in speed results from the dielectric isolation techniques used in the Harris line. Inseleks' SOS (silicon-on-sapphire) line achieves speeds to 20 MHz. Motorola's McMOS family, offering unified family-oriented specifications and consistent input-output interface parameters, overcomes basic 4000 Series weaknesses.

Silicon-gate and ion-implantation technologies offer improvements in speed, lower threshold voltages and increased circuit densities. Products using these technologies are now available. However, the 4000 Series is still today's CMOS leader.

CMOS—the growing giant

CMOS has accelerated into widespread use and acceptance in today's broad logic applications. Proponents of this emerging technology have conjured up such flattering labels as:

- The ideal logic
- An LSI technology
- Lowest quiescent power
- A high-rel technology
- High-noise immunity

How valid are these labels? The thrust of the answer is to understand that CMOS is merely one of many competing ways to produce an IC logic component. P-Channel MOS and N-Channel MOS are two other volume MOS technologies. CMOS gates having become large-volume products, will continue to dominate the marketplace at circuit levels up to LSI complexity. At this level, the higher chip packing densities of PMOS and NMOS will dominate and prevent serious CMOS market penetration.

Our "growing giant" theme reflects the phenomenal sales growth of CMOS. Since the introduction of three 4000 Series types in 1968, the sales base has grown to the point where it should exceed $130 million in 1974. Present market forecasts show CMOS products will parallel the growth of TTL, and, in fact, will exceed TTL within the next five years. Functionality and second source availability are two indicators of family health. Manufactured by over 20

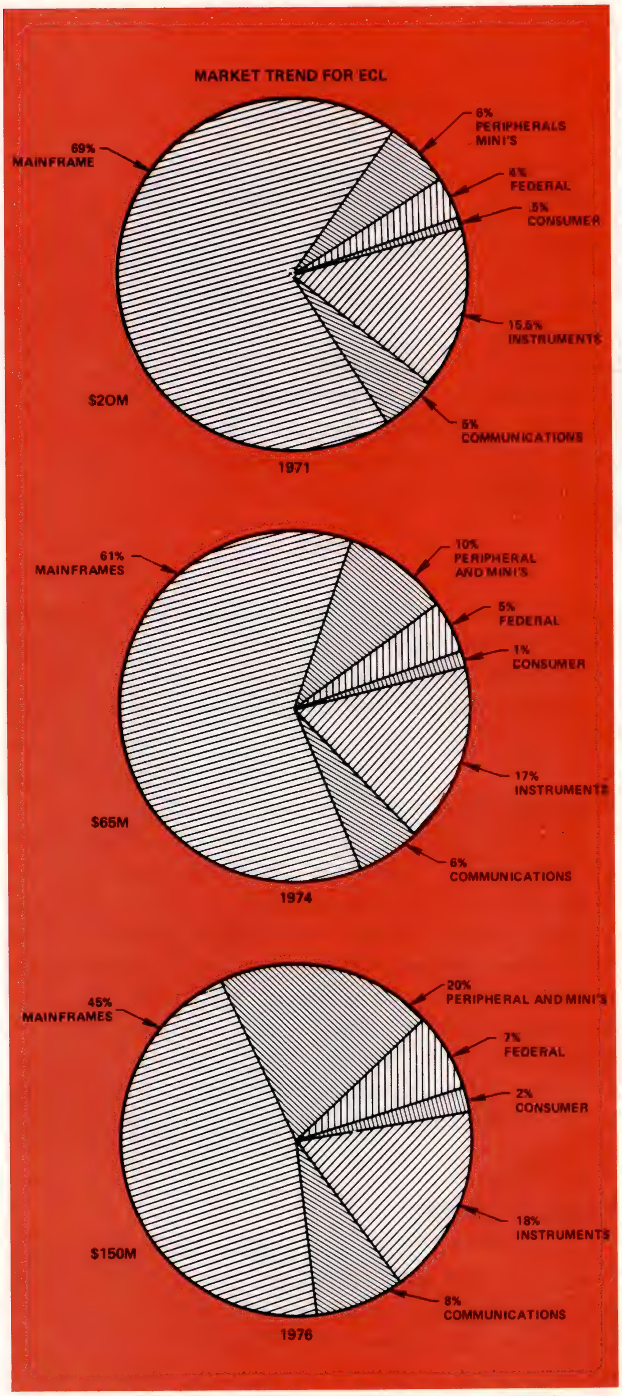


Fig. 3—ECL is big in mainframes, but its marketplace is expanding.

suppliers and with a standard product base of over 150 functions, CMOS definitely qualifies as healthy.

What are its virtues?

An insight into the principal attraction of CMOS can be gained by looking at where it's being used. **Table 1** defines today's predominant applications. They range from watches to satellites, with medical, military and public safety equipment being well represented. The virtues of CMOS,

that generate such widespread usage, range from unique to competitive.

CMOS has an almost ideal set of logic circuit characteristics. As shown in **Table 2**, it is superior to TTL in all areas except speed and actual gate cost. However, when all system costs are considered, CMOS usually costs less.

Because CMOS is used in a similar way to TTL, wide industry experience prevails. Its power supply requirements are simple and generally require no regulation. It also will tolerate relatively high-impedance power distribution. Then too, CMOS interfaces easily with other technologies, requiring only one power supply voltage and no special logic level converters. These technologies include: TTL in all forms (normal power, low power, high threshold and Schottky), DTL, PMOS and NMOS.

Most of the standard CMOS logic functions available today are in the informally standardized 4000 Series. They include such popular circuits as: gates, inverters, buffers, latches, counters, static RAM's, arithmetic circuits, display decoder/drivers, registers and multiplexers. Custom CMOS circuits are popular because custom circuits are easily breadboarded with standard 4000 Series circuits. High packing densities with CMOS LSI to thousands of equivalent transistors are possible, making such IC's cost and size effective for many new systems designs.

CMOS has several excellent attributes for hi-rel use. These include: little or no power dissipation (chip heating), low voltage operation (lower electric fields on chip), relative insensitivity to high parameter shifts (input gain and thresholds) and good radiation resistance (insensitive to bulk device life-time effects).

Now for the bad news

Despite all the obvious advantages of CMOS, caution must be exercised for its proper and safe usage. Static discharge due to incorrect handling can cause gate oxide damage. Floating inputs may also cause malfunctions and device damage.

Additionally, differences in output drive level may occur between different vendors for the same CMOS type, so data sheets should be consulted. Switching points also vary, with as much as a ±20% unit to unit "window" possible.

CMOS gates typically draw 10 nW of quiescent power, with a transient peak of 0.3 mA during switching at 5V. This current will rise to 0.7 mA at 15V, so it must not be ignored.

With the exception of the silicon-on-sapphire (SOS) technology, it must be admitted CMOS is not a high-speed logic form. Clock rates up to 1 MHz (5V) and 5 MHz (10-15V) should be considered the practical limit. Operation to 10 MHz is possible only with specifically designed parts, so adherence to data sheet limitations is essential.

Finally, although some special-purpose line and LED drivers are available, CMOS output drives are not generally intended for driving heavy loads such as lamps and relays.

CMOS of the future

Metal gate CMOS technology will continue to dominate, with major thrust toward increased packing densities and tighter design rules leading to larger and more complex LSI circuits. Insulated-substrate CMOS (SOS) will evidence a rapid growth in the area of high-speed MSI and LSI products. There will be more emphasis on Tri-state and high-current (bipolar) outputs. It seems likely that the functional capability of the 4000 Series will expand to eventually exceed that of 7400 TTL. Expansion of ROM's and RAM's for high-speed/lower power sockets, where larger PMOS and NMOS memory chips are not justified will be another area of expansion.

In summary, within a few years, CMOS should be a mature semiconductor giant, and the pervasive technology of the '70's. □

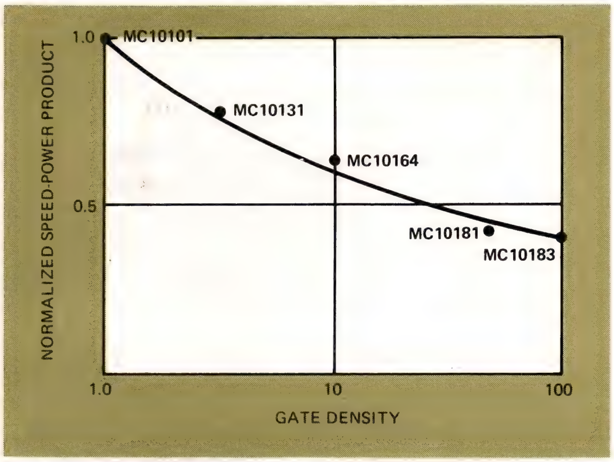


Fig. 4—As circuit density increases from simple gate (M10101) to that of a multiplier (MC10183), ECL efficiency improves.

EDN wants to thank the following individuals for their excellent and expert assistance in the preparation of this article

Stan Bruederle, TTL Product Planning Manager, Signetics, "System improvement simplified."
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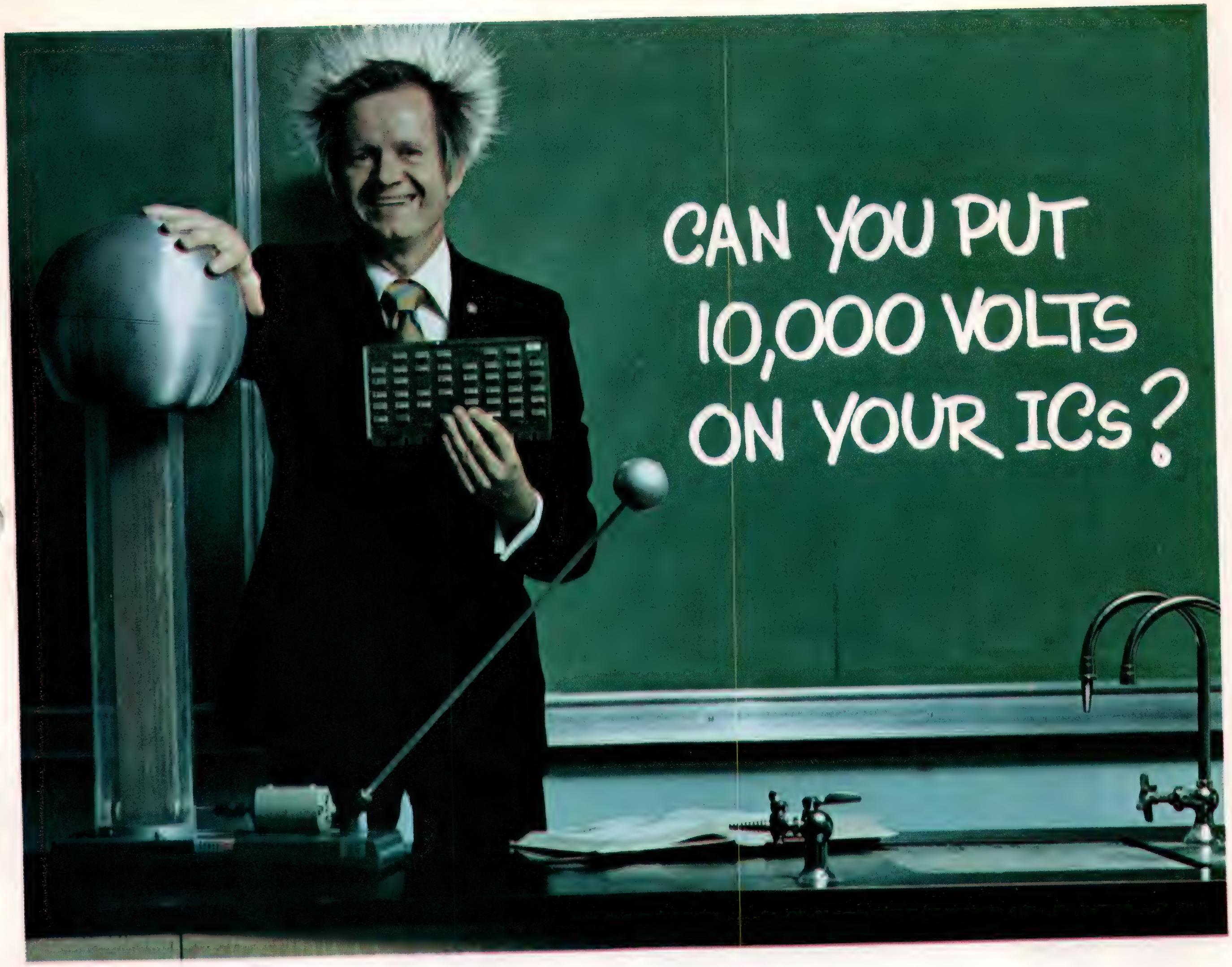

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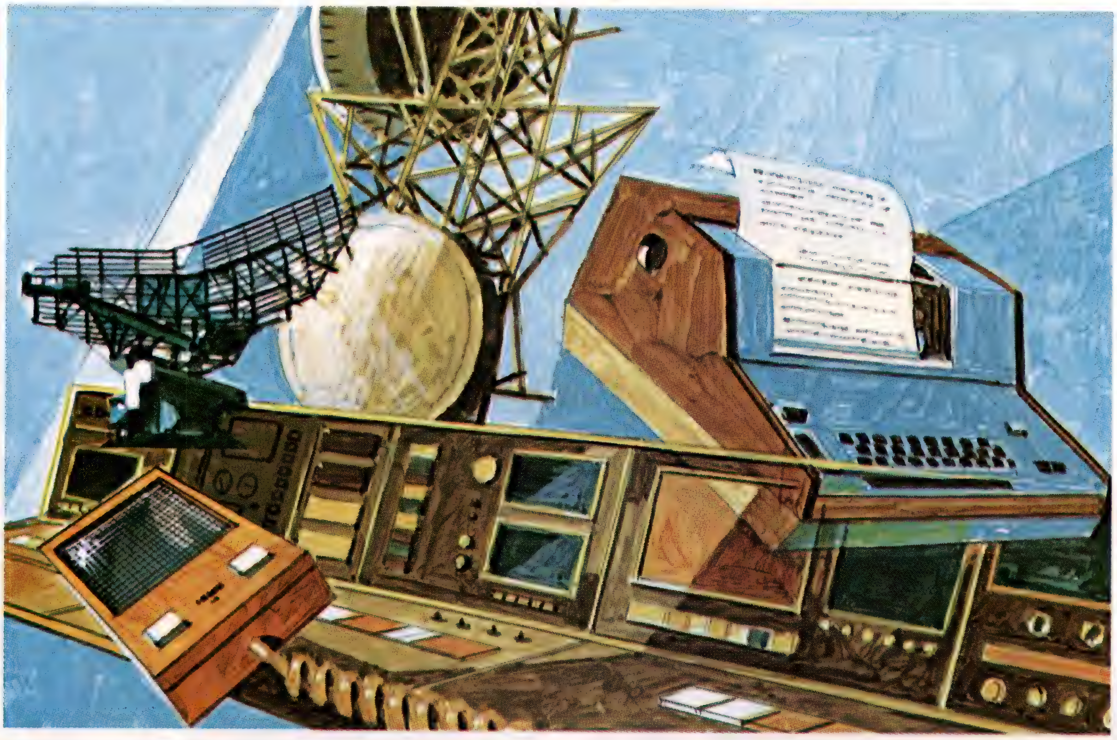

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Dickson has a big new name

New applications open for reciprocal frequency counters

External gating makes it possible to use the reciprocal counter for a wide variety of measurements on time-varying phenomena.

David Martin, Hewlett-Packard

When you have to measure pulsed RF signals, high-resolution FM deviation, Doppler radar profiles or swept signal linearity, or maybe determine voltage-controlled oscillator (VCO) response, the gated reciprocal frequency counter might be the answer. While the reciprocal frequency counter has been with us for some time, the externally gated mode is a relatively new concept. This article presents a brief overview of the gated concept and then describes the new applications made possible by it.

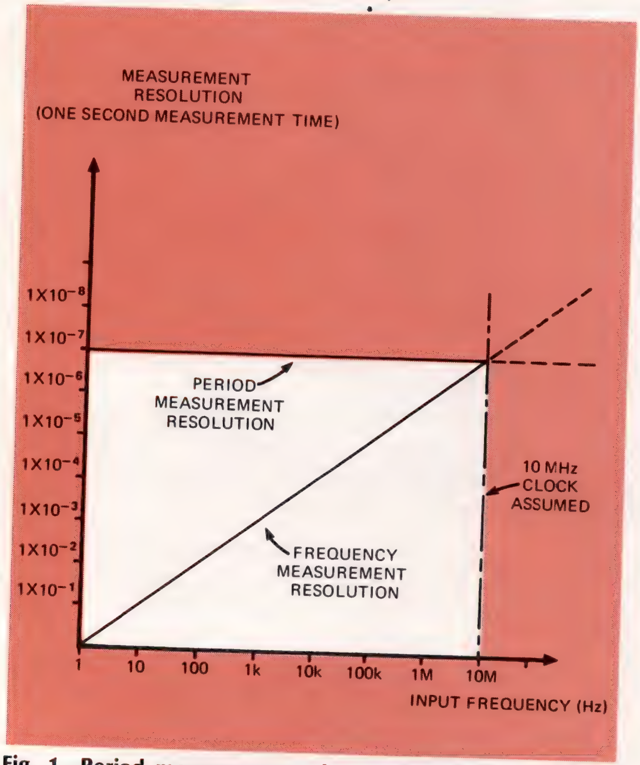

Fig. 1—Period measurements always have better resolution than frequency measurements for input frequencies less than the counter's internal clock.

The reciprocal counter is so called because in operation the instrument measures the period of the input signal and then computes and displays the corresponding frequency. The ready availability of complex IC's has made the reciprocal counter commonplace in the industry.

A major advantage of the reciprocal counter is the increased measurement resolution it provides. As **Fig. 1** indicates, for the same measurement time, period counting always provides more resolution (and accuracy) than the equivalent conventional frequency counter, provided the input frequency is less than that of the counter's internal clock frequency.

The reciprocal counter finds major application in low-frequency measurements (power line, engine speed, etc.) because of its resolving power. Using the example of **Fig. 1,** a 60-Hz measurement with a conventional counter produces a resolution of 1/60, whereas with the equivalent reciprocal counter the resolution is 1×10^{-7}, a five order of magnitude improvement.

Use of higher frequency clocks has also opened a new area of application for the reciprocal counter, namely precision measurements on high-stability oscillators. A reciprocal counter with a 500-MHz clock can resolve a 1-MHz input to 0.002 Hz in one second; some 500 times improvement over any conventional frequency counter.[1]

Gated measurements open new vistas

A second, and more subtle, feature of period counting lies in the fact that the counter's gate is synchronous with the input signal. This gives the user, potentially at least, the ability to control at what point in real time and for how long a

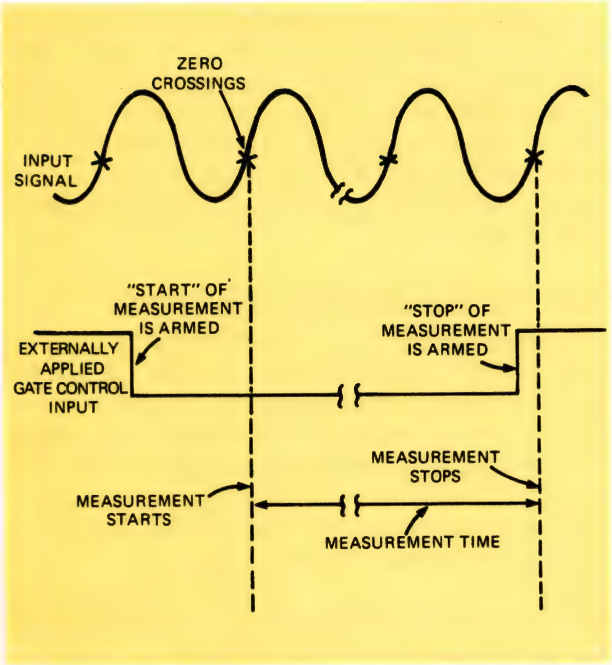

Fig. 2—External gate control signal can select the starting point and measurement time of period measuring frequency counter.

measurement will take place. User control is via an externally applied gate control signal (**Fig. 2**).

What is the benefit to the user of this mode of operation? The most obvious is in the direct measurement of pulsed RF signals. Simply gate the counter ON during the burst and the measurement is made (**Fig. 3**).

Since the counter is externally gated, it makes no difference whether the input signal is pulsed RF or CW. The measurement is made direct, and therefore no degradation takes place in either accuracy or resolution.

The ability to make gated frequency measurements, rather than the average measurement the conventional frequency counter performs, has far greater application potential than just the direct measurement of PRF frequencies. In general, one would use the gated mode for measurements on time varying phenomena. For example, the response of a voltage-controlled oscillator to a step function of voltage input may be determined by gating the counter at a series of times delayed from the stimulus (**Fig. 4**). Along the same lines, linearity of a swept-frequency signal can also be determined by gating at known points in time as the signal is being swept (**Fig. 5**).

In the area of frequency-modulation measurement and analysis, FM deviation may be measured by gating the counter at points in time relative to the modulating signal (**Fig. 6**). A byproduct of this measurement is the determination of any phase shift between the stimulus (modulation input) and the response (the modulated carrier). In addition, any distortion that results from the modulation process can also be observed.

One other application of the gated mode worth mentioning is that of extending the direct measurement of pulsed RF carrier frequencies to frequency profile measurements, where the frequency is shifted across the pulse (**Fig. 7**). Measurements such as this find application in Doppler, frequency-agile and pulse-compression radar systems.

It can be seen from these applications that the combination of external gating and real-time frequency measurements opens a whole new domain to the period measuring frequency counter. Although it is true that the conventional frequency counter can be designed to perform these measurements, it suffers from three major limitations:

- There is an uncertainty in the starting point of the measurement, equal to the minimum gate time.

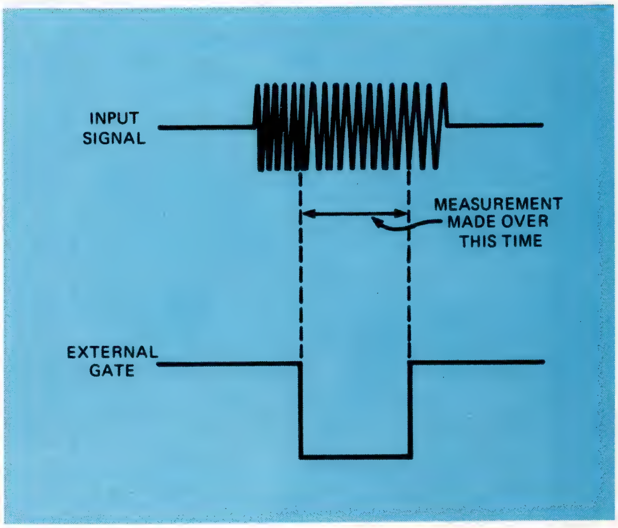

Fig. 3—External gating and direct measurement of pulsed RF signals provide the same accuracy and resolution as for CW inputs.

- The available gate times are usually limited to decade steps such as 1 μsec, 10 μsec, etc. Conversely, the gate or measurement time is determined by the width of the gate control input for period counters.
- The measurement resolution varies with the frequency being measured and would never exceed that obtained from a corresponding period measuring instrument.

What about counter performance?

It is a relatively simple matter to include external gating in the period-measuring frequency counter. If available, the gate control

input is usually located on the rear panel of the instrument. Probably this input also will be compatible with one of the logic families, such as ECL or TTL, thus making it easy to generate the control signal.

The frequency response of the gated counter should be the maximum possible to fully lend itself to the applications described above. At

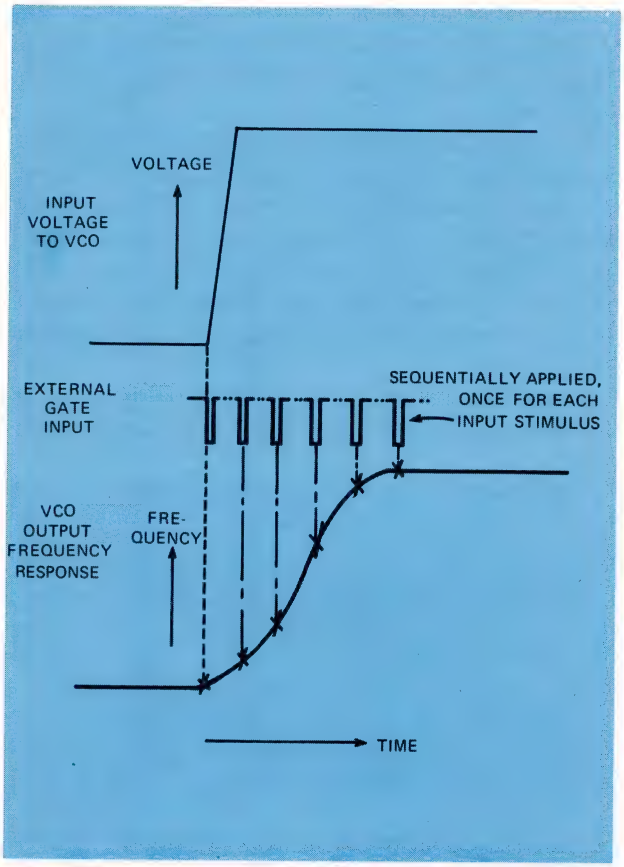

Fig. 4—Characterizing the response of a VCO to a step-function voltage input.

present, the state of the art for direct counting is approximately 500 MHz. This can be extended to the microwave region by heterodyne conversion, where the input signal is heterodyned down to within the range of the counter. If the heterodyne converter happens to be a plug-in to the counter itself, the solution becomes a particularly neat and self contained package. A word of caution, however—rapid changes in input-signal amplitude (for example, pulsed RF) can introduce distortion when applied to converters designed for CW signals only. If pulsed RF measurement is the application, a converter whose front end is balanced to the input signal should be used.[2] Coverage to 18 GHz is possible with heterodyne converters presently available.

Minimum gate width is another important parameter. It dictates the minimum time window over which the signal can be measured. Clearly the minimum measurement time is one cycle of the input signal. At 500 MHz, however, this represents 2 nsec. Such a narrow window is of questionable value and, in addition, would be inordinately expensive. The optimum cost/performance tradeoff lies at about 50 nsec, a time which is shorter than most high-resolution radar pulse widths.

Freq. averaging boosts resolution

The above impressive state-of-the-art specifications notwithstanding, consider the resolution obtained with a gate width of 50 nsec. If we assume our counter has a 500-MHz clock, then the measurement resolution becomes 2×10^{-9} per second of measurement time. Since, however, the measurement time is only 50 nsec, the actual resolution becomes 4×10^{-2}, or just 4%.

Frequency averaging can help to overcome this.[2] Its concept is identical to time interval averaging, found in several universal counters today. Basically, the averaging concept says that if N measurements are taken and averaged, the

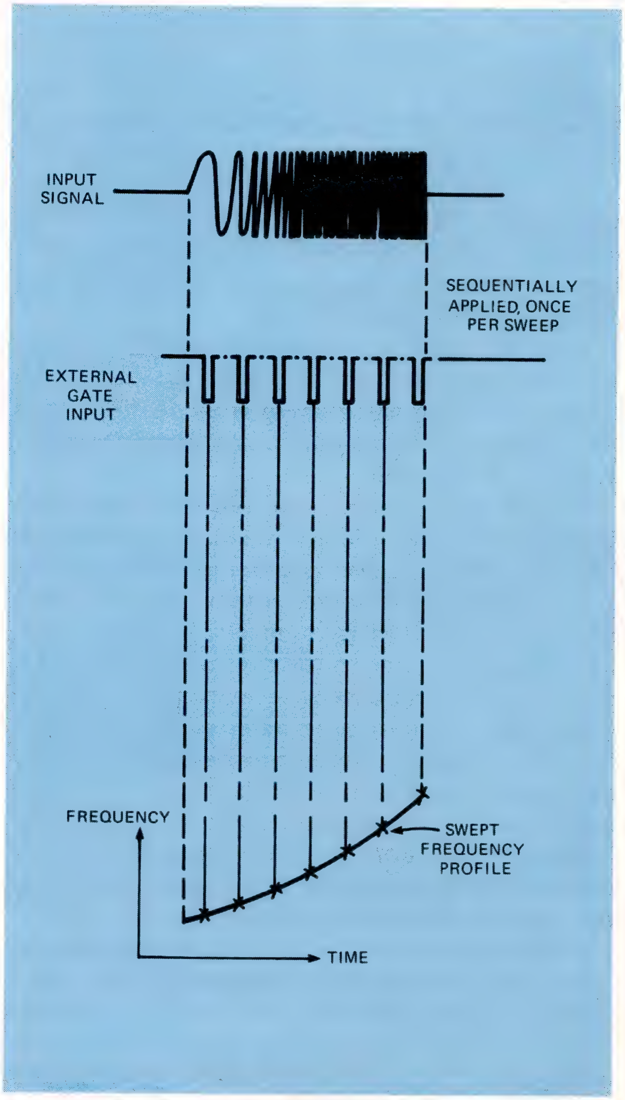

Fig. 5—Determining the linearity of a swept signal.

time measurement resolution improves as $1/\sqrt{N}$. The only necessary conditions are that the input be repetitive, obviously, so that the N measurements can be taken; and that the input frequency and clock frequency be asynchronous so that the inherent ±1 count uncertainty condition will exist from measurement to measurement.

The limit to which averaging can improve resolution is based on the noise level within the

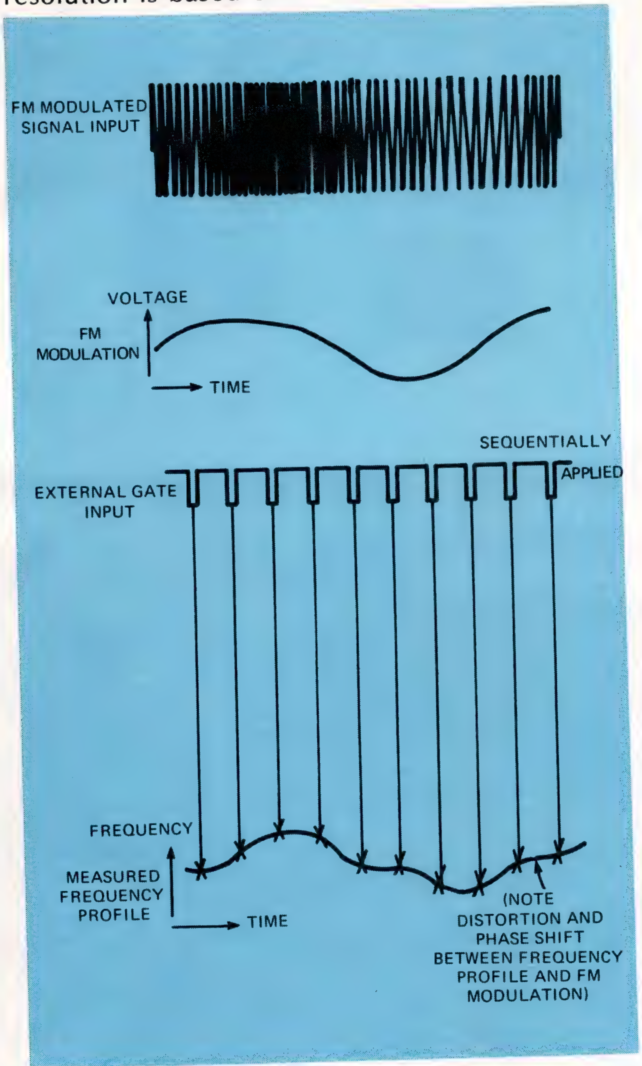

Fig. 6—Measuring the deviation of a frequency-modulated signal.

counter itself. For a well designed high-speed instrument, 1 psec is a practical value. Thus, an improvement in resolution of a little more than 10^3 can be achieved. Nevertheless, in the example above, our measurement resolution now becomes 4×10^{-5} despite the fact that the measurement window is only 50-nsec wide.

In absolute terms, the worst-case resolution would occur for a 500-MHz input, and is $5\times10^8 \times 4\times10^{-5} = 20$ kHz. Thus, if 50 nsec can be viewed as instantaneous, it is now possible to resolve instantaneous frequency measurements to 20-kHz resolution. Modern component technology has made this truly amazing performance possible. It is this performance which, in turn, makes the potential applications of gated frequency measurements a practical reality.□

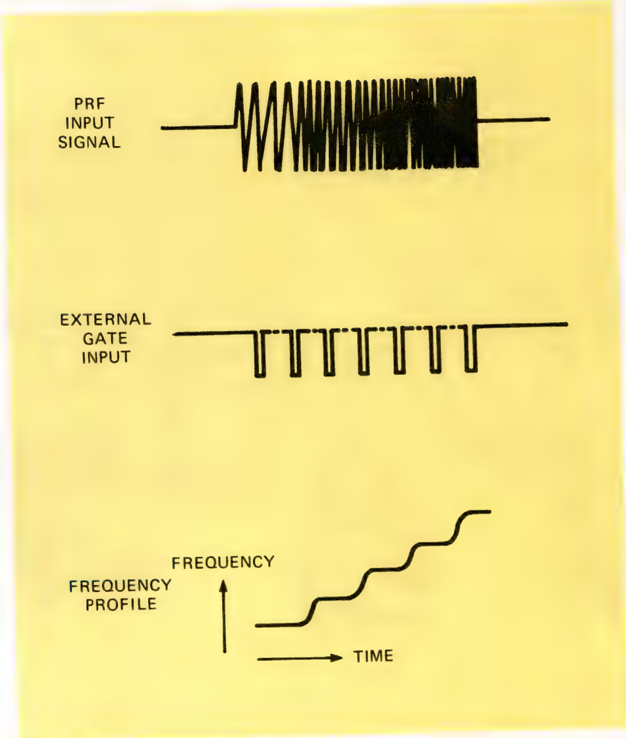

Fig. 7—Determining the frequency profile of a PRF signal.

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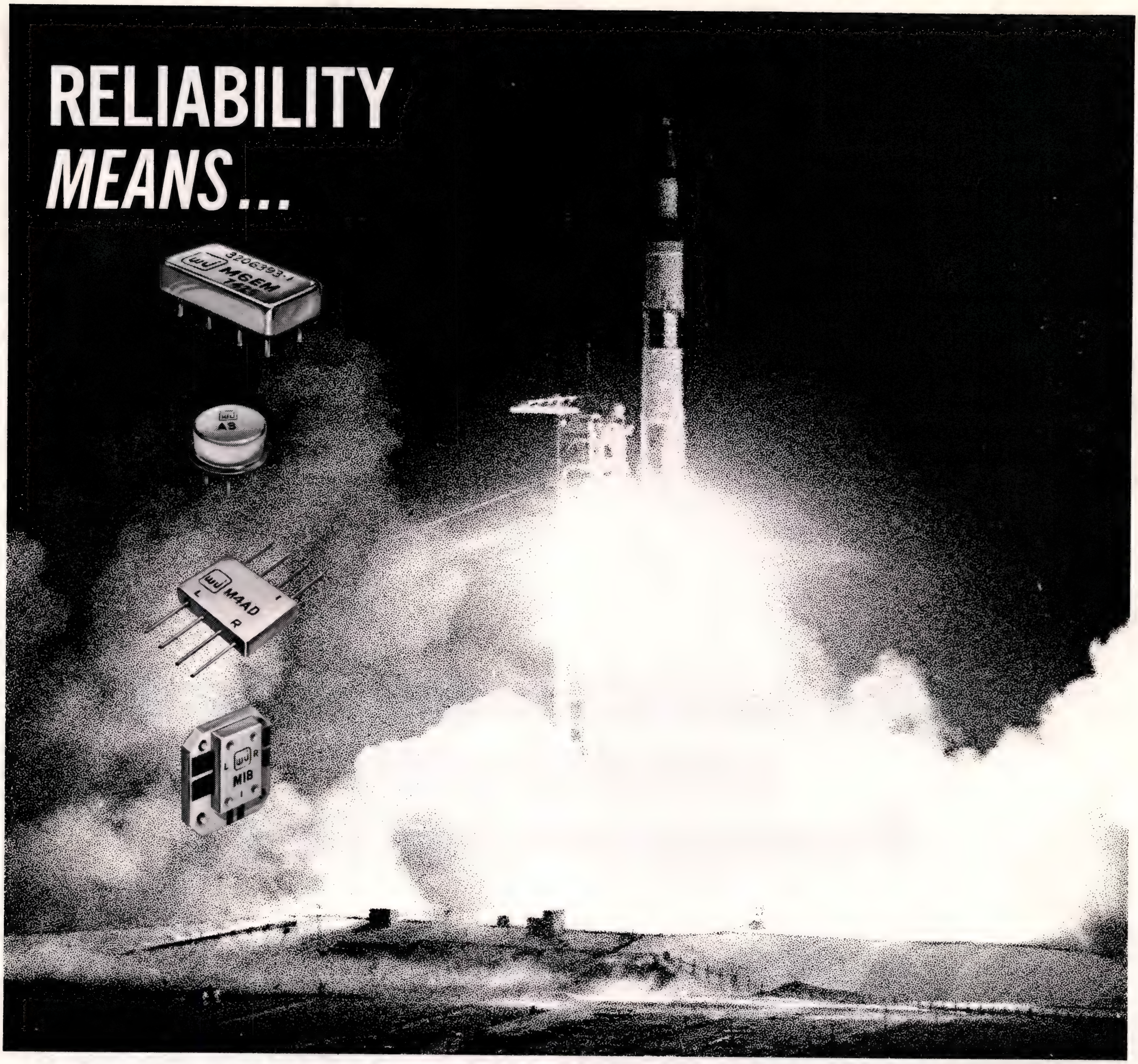
1. *Hewlett-Packard Application Note 172, "The Fundamentals of Electronic Frequency Counters."*

2. *Hewlett-Packard Application Note 173, "Recent Advances in Microwave Pulsed RF Measurements."*

Author's biography

Dave Martin is a product marketing manager at the Santa Clara Div. of Hewlett-Packard. With HP for eight years, Dave presently holds marketing responsibility for the counter-printer product line. Dave received his engineering degree from the University of Sydney, in Sydney, Australia, and presently lives in Los Altos, CA.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Low cost VCO driver amplifiers really perform if designed right

When you need high performance VCO drivers, IC's just won't do the job. This design saves time and money, yet slews over 4000 V/μsec.

Haim Bunin, Haifa, Israel

Voltage-controlled oscillators (VCO's) are widely used in modern electronic systems. Unfortunately, many VCO's need modulation amplifiers with 40-60V outputs, so standard IC's can't be used. To solve this problem you may be able to buy the VCO with a built-in driver or buy a separate high-performance amplifier. But such solutions are likely to be very expensive and delivery may be unacceptably slow.

As an alternative, you could consider building your own driver amplifier, a task which needn't be overwhelming. Step-by-step, this article will lead you to a truly high-performance design featuring large-signal modulation rates up to 20 MHz for 60V varactors, small-signal bandwidths up to 86 MHz, and slew rates exceeding 4000 V/μsec. Moreover, this design is simpler and less expensive than other approaches and offers improved performance merely by changing the basic building block—an op amp.

Will buffering remove the headache?

The easiest and most direct way to build a 60V driver amplifier is to add a buffer stage to a standard IC op amp (**Fig. 1**). A specific example of a basic circuit (**Fig. 2**) points out the significant limitations of this approach, however. The composite amplifier's slew rate is poor, its bandwidth is limited, and it can't handle capacitive loads. Since VCO's can present loads of 20 to 100 pF, the latter limitation makes **Fig. 2's** design an impractical solution to our problem.

A good voltage buffer should have high input and low output impedances, high slew rate and sufficient output current drive capability. To eliminate oscillations, its delay should be small compared to that of the input amplifier. Of course, dc stability of the circuit will be controlled exclusively by the input amplifier, so drift of the buffer is not critical.

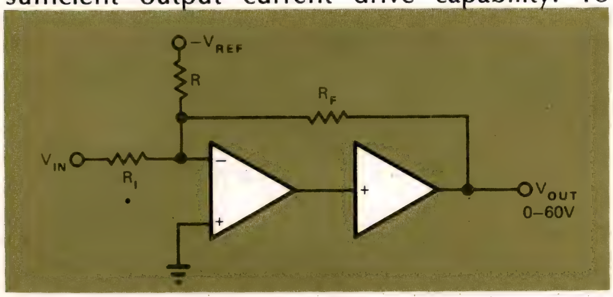


Fig. 1—Adding a buffer output stage to an op amp is the most direct way to build a 60V VCO driver amplifier.

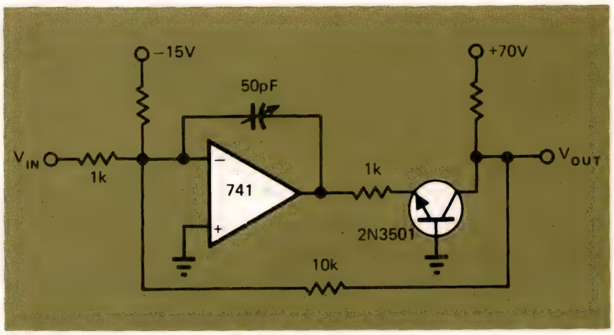


Fig. 2—Poor slew rate, limited bandwidth and restricted capacitive load drive capability are important limitations of this simple VCO driver design.

The circuit of **Fig. 3** meets these performance criteria. It incorporates a fast input op amp, a voltage buffer and a simple compensation technique. C_2 is trimmed for stability, while C_1 is adjusted to increase slew rate and bandwidth. By replacing the op amp and transistors with higher frequency types, the dynamic characteristics improve.

Referring to **Fig. 3**, observe that circuit gain is:

$$A = -\frac{R_F}{R_I}$$

while the dc level in the output is:

$$V_{OUT} = +15\left(\frac{R_F}{R}\right)$$

Similarly, open-loop gain for the circuit is:

$$V_{OL} = -A_{OL1}\left(\frac{R_T}{R_K}\right)$$

where A_{OL1} is the open-loop gain of the op amp.

Full power output (at 60V p-p) is 1 MHz and this circuit slews at 200 V/μsec. Small signal bandwidth is 5 MHz.

What's that connection?

A substantial improvement in VCO driver amplifier slew rate, bandwidth, settling time and gain-bandwidth product results when the input op amp operates in the transimpedance (Z_T)

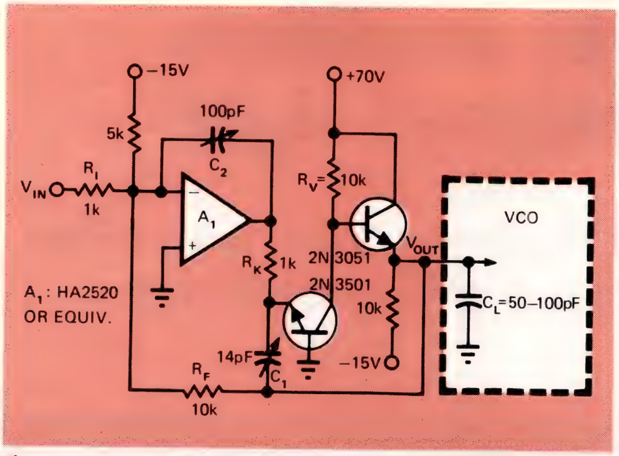


Fig. 3—C_2 trims stability, while C_1 increases slew rate and bandwidth in this moderate-performance driver. Slew rate is 200 V/μsec; small-signal bandwidth, 5 MHz.

configuration (**Fig. 4**). The associated buffer amplifier now has high gain, rather than low gain as was previously the case.

There are two reasons for the performance improvement. First, the transimpedance connection is fast and has low delay. Second, since this configuration permits the use of a dynamic load with the high gain buffer, slew rate improves. **Fig. 5** shows a simplified schematic of a high slew rate differential amplifier that operates as such a buffer. It features some very effective compensations for dynamic characteristics.

Specifically, C_1 compensates for C_0, the total collector capacitance of Q_2. This effectively increases the amplifier's slew rate, since:

$$\text{Slew Rate} = \frac{I_{C4}}{C_0 - C_1}$$

where I_{C4} = collector current of Q_4.

Bandwidth of the circuit increases as well, the limit being related to desired dynamic stability.

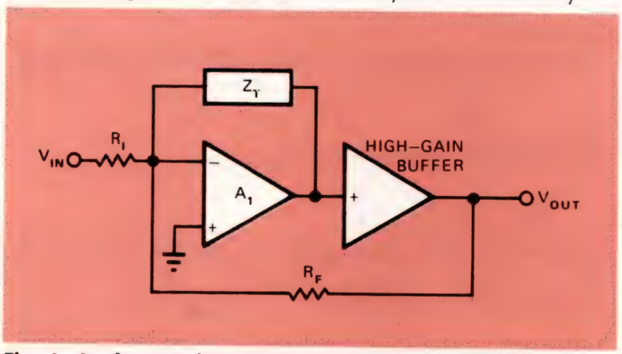


Fig. 4—In the transimpedance configuration, (Z_T), the buffer amplifier operates at high gain. This permits significant improvements in slew rate, bandwidth, settling time and gain-bandwidth product.

Fig. 6 shows the schematic of a complete high-performance VCO driver amplifier. Z_T of the input amplifier is R_4 in parallel with C_3. C_4 determines the dc stability of the total amplifier, but has no effect on high frequency behavior. Dc loop gain is very high.

Q_3 and Q_4 are current sources set up so that $I_{Q3} = 2\,I_{Q4}$. Q_4 also functions as the differential amplifier's dynamic load. C_{10}, the push-pull capacitor, increases slew rate, while R_{17} increases the circuit's capacitive drive capability. When the load capacitance is greater than 30 pF, R_{17} should be increased to 60Ω.

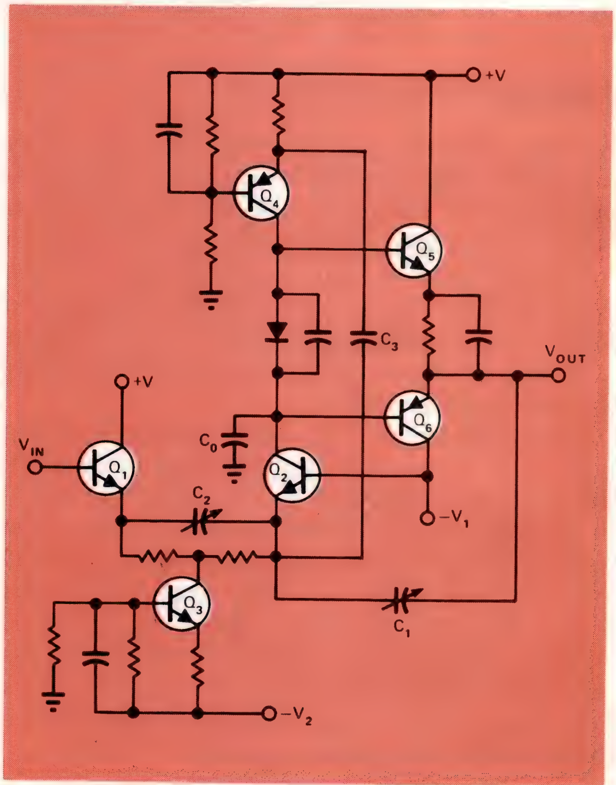


Fig. 5—High-gain, high-performance buffer uses C_1 to compensate for C_0, thus effectively increasing slew rate.

Circuit is well-behaved

A more detailed discussion of the amplifier's dynamics is appropriate at this point. C_1 controls the dominant pole of the amp, which occurs at $f = 1/2\pi\ R_t\ (C_0 - C_1)$. R_t in this equation is the effective collector-base resistance of Q_2, Q_4, Q_5 and Q_6 in parallel, while C_t is the effective collector capacitance of the same transistors.

C_2 controls a zero at $f = 1/2\pi\ (2\ R_E C_2)$. The unity-gain time constant of the input amplifier and R_4C_3 creates a second pole. When there is pole-zero cancellation, the dominant pole remains and the closed loop gain is given by:

$$A_V = -\frac{R_F}{R_I}\left(\frac{1}{1 + S\left[2\ R_E(C_0 - C_1)\left(\frac{R_F}{R_3}\right)\right]}\right)$$

Trimming of the circuit is quite straightforward. Begin with C_1 and C_2 adjusted to minimum capacitance and C_3 adjusted to maximum. Then

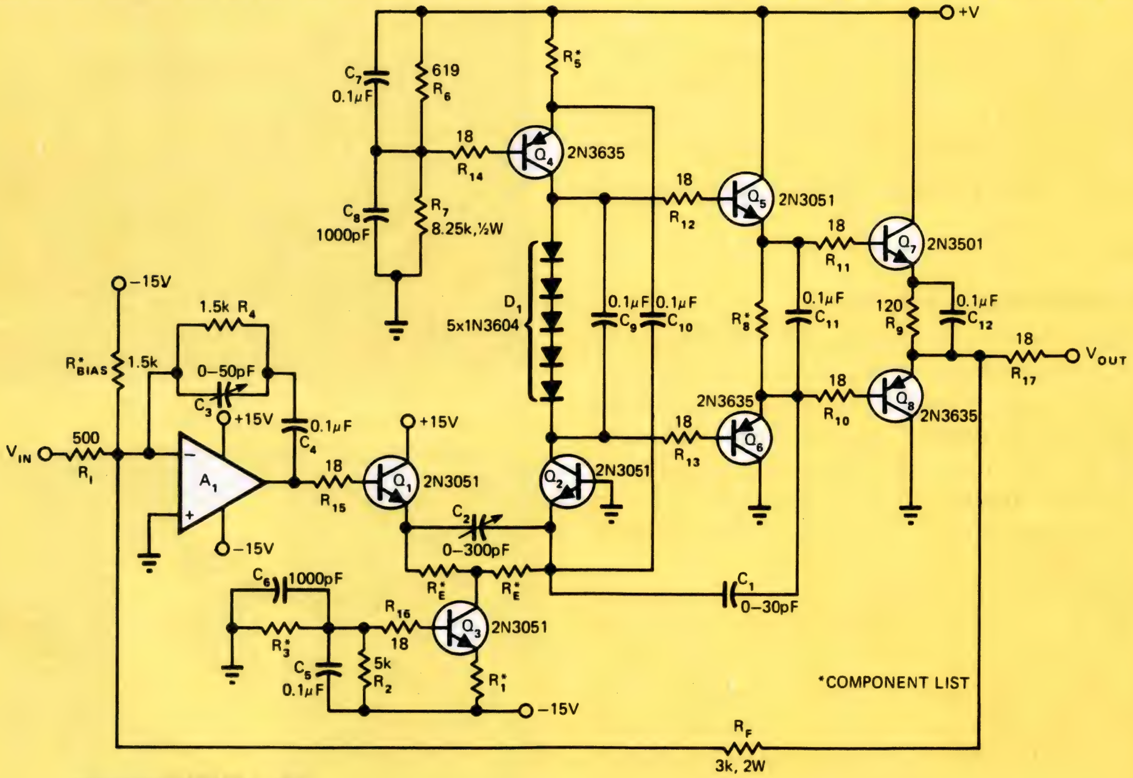
How to get high slew rate

The following design hints for maximizing slew rate were incorporated into the circuit shown in **Fig. 6**.

1. Decrease the dominant capacitance by using the effect of negative capacitance (C_1 in **Fig. 6**).
2. Use a dynamic load in the high-gain output buffer.
3. Use a push-pull capacitor (C_{10} in **Fig. 6**).
4. Use an output stage (typically an emitter follower) that can supply sufficient current to the capacitive load to charge it at the desired maximum frequency.

$$\text{MAX } I_{OUT} \geq V_{MAX}\left(\frac{1}{R_L} + 2\pi f_{MAX} C_L\right)$$

5. Keep the phase and gain margins of the total amplifier to the minimum values necessary to meet stability requirements.
6. Increase slew rate of the IC op amp by input compensation, if possible.
7. Choose transistors that maximize the quotient $P_{TMAX}/C\mu$, where P_{TMAX} is power dissipation in T_{MAX} and $C\mu$ is collector capacitance.



***COMPONENT LIST**

COMPONENT	HIGH PERFORMANCE DRIVER–AMPLIFIER	ECONOMY DRIVER–AMPLIFIER	NOTES
A_1	M.S. KENNEDY MODEL 770	HARRIS HA 2525 OR HA 2520 (−55 TO +125°C)	OTHER "WELL–BEHAVED" OP–AMPS (−6dB/OCTAVE ROLLOFF) CAN ALSO BE USED.
R_E	250	180	
R_{BIAS}	1.5k	1.5k	FOR +30V DC LEVEL AT OUTPUT
R_1	100	174	
R_3	4.3k	10k	
R_5	170	382	
R_8	90	150	
HEAT SINKS FOR Q_2, Q_3, Q_4, Q_5, AND Q_6	JERMYN A1004BE	JERMYN 4405	
HEAT SINKS FOR Q_1, Q_7 AND Q_8	JERMYN 4405	JERMYN 4405	
+V SUPPLY	+80V	+70V	

Fig. 6—Two versions of this high-performance VCO driver amp are offered. The high-performance circuit slews at 4000 V/μsec and features gain bandwidth products to 8 GHz. The "economy" version, with its 1200V/μsec slew rate, 20 MHz small-signal bandwidth and −55 to +125°C operating range, is suitable for hybridization.

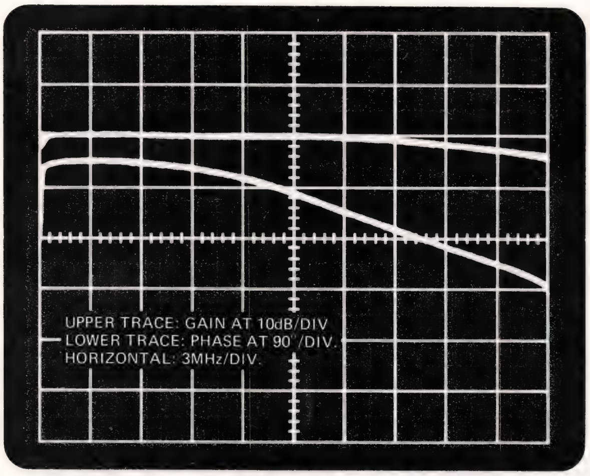


Fig. 7—Large-signal (60V p-p) response is 20 MHz.

increase C_1 and C_2 while decreasing C_3 until maximum performance without oscillation is obtained. When properly trimmed, the complete driver amplifier behaves just like a simple inverting op amp with a gain of $\frac{R_F}{R_I}$. Output dc level is $+15\ (R_F/R_{BIAS})$.

Gain-bandwidth is 8 GHz!

To minimize any problems when building the VCO driver amplifier of **Fig. 6**, several practical hints should be noted. The circuit should be mounted on a ground plane board. Resistors should be 1% metal film. And power supplies must be decoupled with an LC network (e.g., an 18 μH inductor and a 10 μF capacitor paralleled with 1000 pF).

Rewards for careful construction are considerable. **Fig. 7**, the large-signal bode plot at a gain of six, shows response at 60V p-p to be 20 MHz. Small-signal response is flat to over 50 MHz. It can be widened to 86 MHz if a slight (+0.5 dB) ripple can be tolerated (**Fig. 8**). If small-signal bandwidth is important, keep the values of R_F and R_I below 5 kΩ.

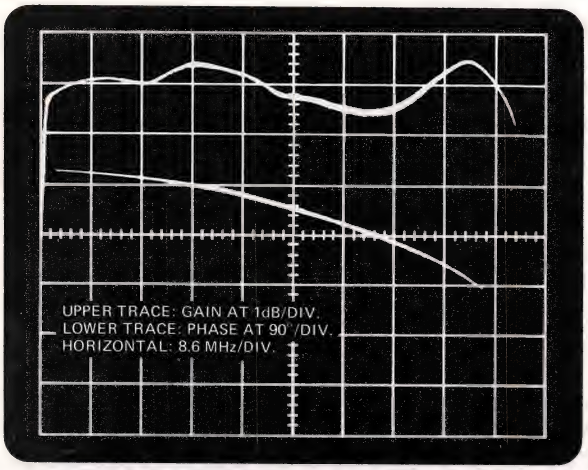


Fig. 8—Small-signal bandwidth, flat to >50 MHz, can be increased to 86 MHz if a ±0.5 dB ripple can be tolerated.

Large-signal pulse response (**Fig. 9**) is also impressive. Fall time is less than 20 nsec for a 58V step. Full power output for 15V p-p is 48 MHz.

The compensating effect of C_1 keeps the bandwidth high even for high gains. For example, at a gain of 200, bandwidth remains 40 MHz; e.g. the gain-bandwidth product is 8000 MHz! However, note that the penalty for using C_1 to increase the large- and small-signal bandwidths is increased ripple. Further increases in slew rate and bandwidth can be effected by replacing the input amplifier with a faster, well-behaved (−6 dB/octave) model.

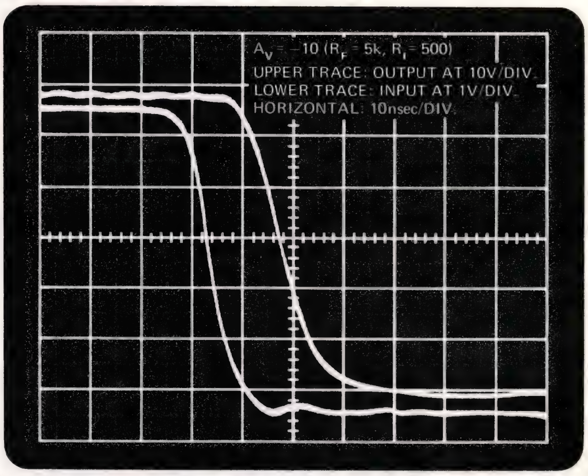


Fig. 9—Less than 20 nsec is required for the output to fall 58V. Full power output for 15V p-p is 48 MHz.

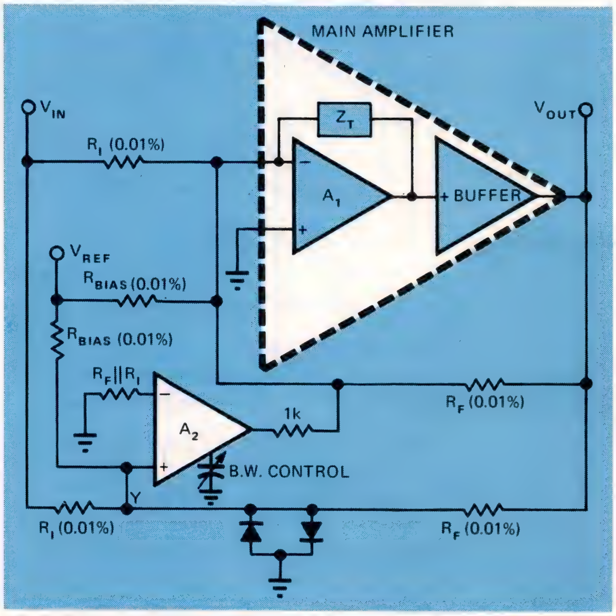


Fig. 10—Loop gain can be increased without sacrificing large-signal performance by using this circuit, (**Ref. 2**). It can be driven by a 12-bit D/A converter.

Even the economy model performs well

If a lowest cost circuit is your objective, the basic VCO driver design can be modified slightly. For instance, use a HA2520 IC op amp as an input amplifier and reduce the power dissipation in the transistors. Such a unit still has a 1200 V/μsec slew

rate and a 20 MHz small-signal bandwidth. With an operating range of −55 to +125°C, it would be also suitable for hybridization and use in military/aerospace or rugged industrial applications. The frequency response limit is mainly due to the additional poles of the HA2520 beyond 20 MHz.

But what about digital control?

The whole world is going digital, or so it seems. Therefore, it is very appropriate to consider the application of our basic driver-amplifier in a digitally-controlled VCO. In such use the most important driver-amp parameters are accuracy and settling time. For instance, consider a system using a 10-bit D/A. All errors must be kept less than 0.1%. For the driver-amp, error sources include noise, ripple, thermal time constants, insufficient loop gain and saturation effects.

Noise is minimized in our VCO driver by using metal film resistors. Noise level is less than 0.01% of full scale. Using a smaller C_1 and/or adding a small (1 to 2 pF) capacitor in parallel with R_F to reduce bandwidth achieves a further decrease in noise.

Ripple is minimized by paying careful attention to grounding. Power supplies should be carefully bypassed and a central ground point used for the amplifier. Also, keep all component leads as short as possible.

Thermal response is traceable basically to the difference in power dissipation in R_F as the output voltage changes. It is noticeable when settling to 0.1% and can be eliminated by changing R_F to a 0.1% metal-film type.

Loop gain is usually sacrificed when very high slew rates are needed. The best way to increase loop gain without interfering with the main amplifier and sacrificing large-signal performance is to use the circuit shown in **Fig. 10** (**Ref. 2**). In this scheme, when a large input step is presented to the input, the main amplifier brings the output

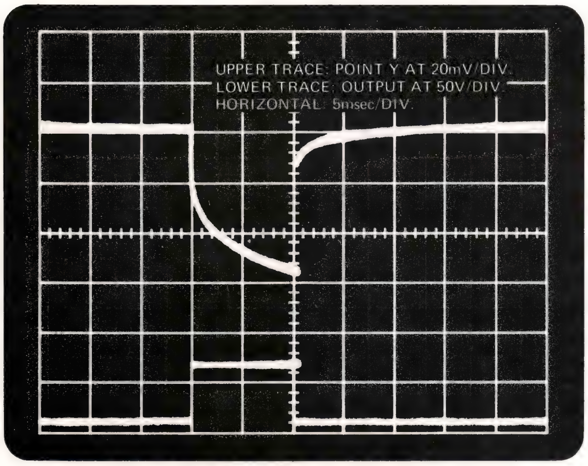


Fig. 11—A 60 mV (1%) error appears at point Y when A_2 is removed from circuit of **Fig. 10**.

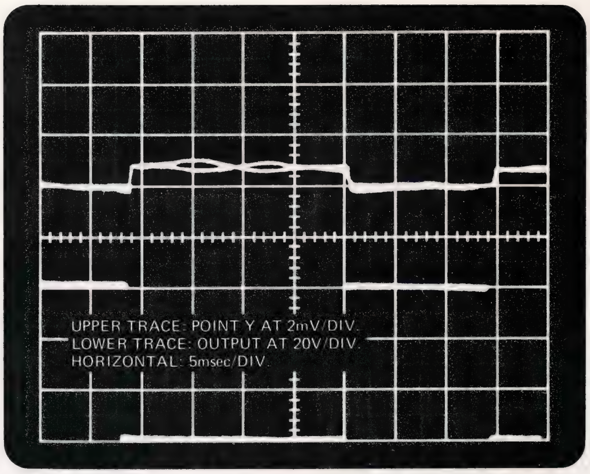


Fig. 12—Adding correction amplifier A_2 to circuit of **Fig. 10** reduces the error at point Y to less than 0.02%. Obviously, A_2 must be a fast amplifier if high performance is required.

to the error limits (e.g., in our amp, a 60V output step to 1% error within 50 nsec). Error is sensed by A_2 at point Y and is corrected to the final value.

To keep high dynamic performance, A_2 must be a fast amplifier. A HA2520 is quite good for this purpose. **Figs. 11** and **12** illustrate error-correction circuit operation. **Fig. 11** shows a slow 60-mV error at point Y when A_2 is removed. This is equivalent to a 1% error on 60V at a gain of 10. A_2 reduces the error to 0.8 mV (**Fig. 12**).

Saturation effects tend to lengthen settling times, especially when large signals are involved. So if you value fast settling time and high accuracy, utilize clamps to prevent saturation. Also, when using the amplifier from 0V, return the base of Q_2 and collectors of Q_6 and Q_8 to a −2V supply, or zener them to that voltage from the −15V supply.□

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Author's biography

Haim Bunin works as a project engineer on a research and development program at the Ministry of Defense in Tel Aviv. A 1971 graduate (B.Sc.) of the Technion (Israel Institute of Technology), he is presently completing his M.Sc. studies.

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Write your own algorithms for the HP-35

Machine-specific algorithms can speed solutions of often-used equations, or even allow nonskilled personnel to solve your problems.

Lee Morin, Massachusetts Institute of Technology

Many algorithms have been published in the engineering press lately, most of which have been general algorithms. A procedure to solve a problem is given, but at each step, the user must translate the general instructions into specific keystrokes. Thus, it is often difficult to understand how to use the algorithm.

Another way of presenting an algorithm is to provide a list of keystrokes. The disadvantage in this is that the list works only with the calculator it was written for. Yet the effort involved in writing a machine-specific algorithm can be justified by two conditions: There must be enough calculators of the particular make in existence, and they must be powerful enough to make the algorithm worthwhile. The HP-35 calculator, that has been purchased by hundreds of thousands of engineers and scientists since its introduction in 1972, satisfies both of these conditions.

If a set of equations is used only once, an algorithm usually can't do much to reduce the work involved. However if an equation is used often enough, an algorithm can be written that simplifies calculator operation. The keys need only be pressed in order, and the problem is solved. Data entry is minimized. Computational steps are minimized. Answers are produced in an orderly way. Confusion over which number is which is prevented. And equations that the user may not know or understand may be contained in the algorithm.

A Reference Table of Algorithm Symbols

Symbol	Explanation
START	No action, just an indication of where to begin.
R	Press the R↓ key once.
E	Press the ENTER↑ key once.
$\sqrt{}$	Press the $\sqrt{x}$ key once.
⇄	Press the x⇄y key once.
Other Combinations of Letters	These will correspond directly to a key on the calculator. Be sure not to confuse "e^x" and EEX.
x (input parallelogram)	Input—Key in the data value corresponding to x. DO NOT PRESS ENTER unless following steps direct you to do so.
? (diamond) Yes / No	Branch—Take the appropriate branch in response to the question inside the diamond.
(box)	Instruction Box—Follow the instructions inside. Usually these will be manual or mental operations to be performed before continuing with the algorithm.
(Any Step)— — XYZ	Output—The display shows XYZ after the step has been performed.
STOP	A logical end to the algorithm. STOP is not always used.
⋮ (Step 1) → (Step 2) (Step 3)	Arrows—Continue the algorithm at the step pointed to by the arrows.

To enter negative data, press CHS and then the number. Do not press "−," this key performs a subtraction.

Using machine-specific algorithms

Let's derive an algorithm from the equation for the distance between two points in space as an example.

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2}$$

Suppose the points are (1, 3, 5) and (2, 4, 6). Substituting these values into the equation, we get the following expression:

$$d = \sqrt{(1 - 2)^2 + (3 - 4)^2 + (5 - 6)^2}$$

The following list of keystrokes shows how we would normally solve this problem on the HP-35:

Key:	*Display shows:*
1	1
ENTER	1
2	2
−	−1
ENTER	−1
x	1
3	3
ENTER	3
4	4
−	−1
ENTER	−1
x	1
+	2
5	5
ENTER	5
6	6
−	−1
ENTER	−1
x	1
+	3
$\sqrt{x}$	−1.732050808

The machine-specific algorithm for this problem would be:

START
x_1
E
x_2
−
E
x
y_1
E
y_2
−
E
x
+
z_1
E
z_2
−
E
x
+
$\sqrt{x}$—Distance between points.

The START command does not correspond to any keystroke, it simply indicates that the following step is the first one. "E" is short for ENTER. The slanted boxes indicate a variable to be keyed in. If negative data is to be entered, press CHS and then the number. The output—indicated by the dashed line—is seen in the display after that step is executed.

This trivial algorithm does little more than contain a rather simple equation. It might save some time if you had a long list of distances to compute, but otherwise its usefulness is limited.

The algorithm approach becomes much more powerful if you have complex expressions to solve. Then storage capability can be used to the fullest extent. Since most people cannot remember five numbers, the algorithm approach offers a clear advantage with complex problem solutions.

If you're accustomed to using the calculator in the usual way, algorithms may seem rather odd. Sequences of keystrokes you don't encounter in normal use are used frequently in the algorithm method. The algorithm writer thinks in terms of building blocks of keystrokes. These building blocks perform functions not included on the calculator keyboard. The repertoire of operations increases, and writing algorithms becomes similar to programming a computer. Before we discuss the details of writing algorithms, let's explore the details of using them.

Instruction boxes: In certain algorithms, the user may be required to take specific action besides pressing keys. A rectangular box gives the user directions. For example:

x

Subtract 1 from N in your head and let this be the new N

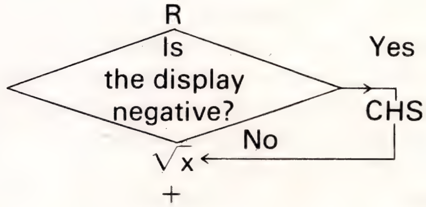
N
x
•

Whatever the old value of N was, subtract one from it and key in this value in the following input step. Then continue with the "x," etc.

Branching: Branching serves two purposes. It provides options for general algorithms and it provides looping and testing for iteration.

A branch consists of a diamond-shaped box with a question inside. Outside the diamond, near the points, lie possible answers to the question. The user follows the path indicated by the correct answer. For example:

•
+
x
R



+
•

After pressing "+ x R," the user looks at the display to see whether or not the value is negative. If it is, he takes the right hand branch. In either case, he ends up at the $\sqrt{x}$.

Error recovery: An incorrect value keyed into the calculator can be corrected provided no other keys are pressed before the error is noticed. Simply press CLX and key in the correct number.

Some algorithms have provision for correcting errors. If an algorithm processes a long list of data, a branch asking if the last entry was wrong may be included. If it was wrong, a sequence of steps to remove the incorrect entry is executed. The user then resumes with the main algorithm.

HP-35 memory review

The HP-35 calculator memory consists of a 4-register stack and one side register. Stack registers are known as X, Y, Z and T. The side register is known as S. Your calculator display always shows the X-register contents.

If ENTER is pressed, the number in X is copied into Y. The number in Y is copied into Z, and the number in Z is copied into T. Any number in T is then lost. This movement of data is called "raising the stack."

Other keys besides ENTER will also raise the stack. For example, the stack raises if a number is brought into X from outside the stack. Keying in a number, pressing RCL or pressing EEX will raise the stack provided the previous keystroke was not ENTER, STO or CLX. If one of these three keys was pressed last, the data in X is in the "volatile" state and will be lost unless ENTER is pressed first.

Pressing the x⇄y key interchanges the contents of X and Y.

Pressing the R↑ key causes the contents of X to go to T, T to Z, Z to Y and Y to X. Pressing R↑ four times in a row allows the user to see the total contents of the stack without changing any values or location.

Pressing STO causes the contents of X to be placed in S. Pressing RCL causes the contents of S to be placed in X. The stack raises unless the RCL follows an ENTER, STO or CLX.

The operation keys also affect the stack. The number in X is always one of the numbers used in an operation. If a "dyadic" operation (one which combines two numbers) is performed, the values in X and Y are combined and the answer is left in X. The stack then drops, the contents of Z go to Y, and the contents of T go to Z. The contents of T remain in T, which allows the calculator to store two constants; one in S and one in T.

If a "monadic" function (a function of a single number) is performed, the contents of X change and the answer is left in X. The rest of the registers remain unchanged, with one exception. Any trig function requires the use of T for internal calculations, so the contents of Z are copied into T and the contents of T are lost.

Writing algorithms using memory maps

A tabular format with six columns is quite convenient for writing algorithms. The left-most column contains the keystrokes and the next five columns show the memory contents after the key has been pressed. If X is in the volatile state (when pressing RCL, etc. does not raise the stack), a "V" is placed in the V column.

A List of Algorithm Segments

1) To see the S register without disturbing the stack except for the T register:

RCL- observe
CLX
+

2) To roll in the opposite direction from the R key:
Press R three times.

3) To produce an unlimited number of copies of two constants:

Use STO with RCL for one

Use ENTER three times for the other. As the stack is dropped, T is copied into Z and T, generating endless copies of T.

4) To truncate a positive number greater than 0.5:

0.5	EEX	Play with this one to get
–	9	different effects.
EEX	–	
9		
+		

5) To take absolute value:

E
x
$\sqrt{x}$

6) To produce a number and its square using only two registers:

E	The number will be in Y and the square
x	will be in Y. This works only with
E	positive values If the values are
$\sqrt{x}$	negative, include a final CHS.

7) To combine a number in X with a number in Y and save a copy of X for later use without disturbing S or Z (T will be lost):

E	X will have f(X, Y)
R	Y will have the old z
f(X, Y)	Z and T will have the old X
	S will be unchanged.

Symbols, as well as numbers, show the contents of memory. **Table 1** lists the contents of the HP-35 memory for various operations.

The quadratic formula: Now, let's use the memory map to derive the algorithm for the formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \text{ when } ax^2 + bx + c = 0$$

This formula can yield several different cases: repeated roots, two real roots or a complex conjugate pair. Forget about the complex case for the time being; this refinement will be added later.

We have three input variables: a, b and c. Since most people think in terms of $ax^2 + bx + c$, the order a, b, c seems natural. If possible, we'll enter the variables in this order.

Our first entry, a, will be needed to calculate a square root, and for a final division. We enter it first and store (step 1 in **Table 2**).

We'll need b to calculate the square root and for a later addition. Enter b next to keep the familiar order (2). Since −b is needed later, we change the sign of b (3).

Press ENTER twice (4). This will leave −b in X, Y and Z. Press x to produce b^2 (5). This leaves −b in Y for later use.

TABLE 1
REFERENCE TABLE OF MEMORY OPERATIONS

TEXT #	KEY	V	X	Y	Z	T		S
			A	B	C	D		E
MONADIC FUNCTIONS:	C^x $\sqrt{X}$ 1/X ln Log		f(A)	B	C	D		E
			A	B	C	D		E
	CLR		0	0	0	0		0
			A	B	C	D		E
TRIG FUNCTIONS	SIN COS TAN, OR ARC		f(A)	B	C	C		E
			A	B	C	D		E
DYADICS	+ − ÷ X X^Y		f(A,B)	C	D	D		E
			A	B	C	D		E
	X⇄Y		B	A	C	D		E
			A	B	C	D		E
	R↓		B	C	D	A		E
			A	B	C	D		E
	E↑	V	A	A	B	C		E
			A	B	C	D		E
	STO	V	A	B	C	D		A
			A	B	C	D		E
	RCL		E	A	B	C		E
			A	B	C	D		E
	CLX	V	0	B	C	D		E
			A	B	C	D		E
	π		π	A	B	C		E
			A	B	C	D		E
	CHS		−A	B	C	D		E
	DEPENDING ON WHAT HAPPENS NEXT, THE UNEXPECTED CAN HAPPEN FOR EXAMPLE							
	CHS		−A	B	C	D		
	F		−F	A	B	C		E
	CHS	PRESERVES VOLATIVITY						

Next, we need the constant 4, a and c, the last data value. To keep the a b c sequence as close together as possible, c will be keyed in first (6). Since c is needed only for the square root, it does not need to be stored.

If 4 is entered now, press the ENTER key to let the calculator know that 4 was not the last digit of c. This keystroke can be avoided if a is recalled (7).

To avoid losing the −b value in T, a and c are multiplied (8). 4 is keyed in and multiplied by ac (9).

We now subtract 4ac from b^2, which leaves the discriminant $b^2—4ac$ in the display (10). If this value is negative, the roots are a complex conjugate pair. In that case we stop (11). Otherwise, take the square root of the discriminant (12).

The quadratic formula generates two answers. It would be nice to have both in the calculator at the end of the algorithm; one in X and the other in Y. Then both can be examined repeatedly by pressing X⇄Y.

TABLE 2
QUADRATIC ROOTS MEMORY MAP

TEXT #	KEY	V	X	Y	Z	T		S
1	$\boxed{A}$		A	0	0	0		0
1	STO	V	A	0	0	0		A
2	$\boxed{B}$		B	0	0	0		A
3	CHS		–B	0	0	0		A
4	E	V	–B	–B	0	0		A
4	E	V	–B	–B	–B	0		A
5	X		B^2	–B	0	0		A
6	$\boxed{C}$		C	B^2	–B	0		A
7	RCL		A	C	B^2	–B		A
8	X		AC	B^2	–B	–B		A
9	4		4	AC	B^2	–B		A
9	X		4AC	B^2	–B	–B		A
10	–		B^2-4AC	–B	–B	–B		A
11			IF DISPLAY IS NEGATIVE, STOP					
12	$\sqrt{X}$		$\sqrt{B^2-4ac}$	–B	–B	–B		A
13	E		$\sqrt{B^2-4ac}$	$\sqrt{B^2-4ac}$	–B	–B		A
14	CHS		$-\sqrt{B^2-4ac}$	$\sqrt{B^2-4ac}$	–B	–B		A
15	R↓		$\sqrt{B^2-4ac}$	–B	–B	$-\sqrt{B^2-4ac}$		A
16	+		$-B+\sqrt{B^2-4ac}$	–B	$-\sqrt{B^2-4ac}$	$-\sqrt{B^2-4ac}$		A
17	R↓		–B	$-\sqrt{B^2-4ac}$	$-\sqrt{B^2-4ac}$	$-B+\sqrt{B^2-4ac}$		A
18	+		$-B-\sqrt{B^2-4ac}$	$\sqrt{B^2-4ac}$	$-B+\sqrt{B^2-4ac}$	$-B+\sqrt{B^2-4ac}$		A
19	R↓R↓R↓		$-B+\sqrt{B^2-4ac}$	$-B-\sqrt{B^2-4ac}$	$-\sqrt{B^2-4ac}$	$-B+\sqrt{B^2-4ac}$		A
20	RCL		A	$-B+\sqrt{B^2-4ac}$	$-B-\sqrt{B^2-4ac}$	$-\sqrt{B^2-4ac}$		A
21	2		2	A	$-B+\sqrt{B^2-4ac}$	$-B-\sqrt{B^2-4ac}$		A
21	X		2A	$-B+\sqrt{B^2-4ac}$	$-B-\sqrt{B^2-4ac}$	$-B-\sqrt{B^2-4ac}$		A
22	STO	V	2A	$-B+\sqrt{B^2-4ac}$	$-B-\sqrt{B^2-4ac}$	$-B-\sqrt{B^2-4ac}$		2A
23	÷		$\frac{-B+\sqrt{B^2-4ac}}{2A}$	$-B-\sqrt{B^2-4ac}$	$-B-\sqrt{B^2-4ac}$	$-B-\sqrt{B^2-4ac}$		2A
24	X⇄Y		$-B-\sqrt{B^2-4ac}$	$\frac{-B+\sqrt{B^2-4ac}}{2A}$	$-B-\sqrt{B^2-4ac}$	$-B-\sqrt{B^2-4ac}$		2A
25	RCL		2A	$-B-\sqrt{B^2-4ac}$	$\frac{-B+\sqrt{B^2-4ac}}{2A}$	$-B-\sqrt{B^2-4ac}$		2A
25	÷		$\frac{-B-\sqrt{B^2-4ac}}{2A}$	$\frac{-B+\sqrt{B^2-4ac}}{2A}$	$-B-\sqrt{B^2-4ac}$	$-B-\sqrt{B^2-4ac}$		2A
26	X⇄Y		$\frac{-B+\sqrt{B^2-4ac}}{2A}$	$\frac{-B-\sqrt{B^2-4ac}}{2A}$	$-B-\sqrt{B^2-4ac}$	$-B-\sqrt{B^2-4ac}$		2A

TABLE 3
MEMORY MAP FOR THE COMPLEX ROOTS CASE

TEXT #	KEY	V	X	Y	Z	T		S
			B^2-4ac	$-B$	$-B$	$-B$		A
A	CHS		$4ac-B^2$	$-B$	$-B$	$-B$		A
B	$\sqrt{X}$		$\sqrt{4ac-B^2}$	$-B$	$-B$	$-B$		A
20	RCL		A	$\sqrt{4ac-B^2}$	$-B$	$-B$		A
21	2		2	A	$\sqrt{4ac-B^2}$	$-B$		A
21	X		2A	$\sqrt{4ac-B^2}$	$-B$	$-B$		A
22	STO		2A	$\sqrt{4ac-B^2}$	$-B$	$-B$		2A
23			$\frac{\sqrt{4ac-B^2}}{2A}$	$-B$	$-B$	$-B$		2A
24	$X \rightleftarrows Y$		$-B$	$\frac{\sqrt{4ac-B^2}}{2A}$	$-B$	$-B$		2A
25	RCL		2A	$-B$	$\frac{\sqrt{4ac-B^2}}{2A}$	$-B$		2A
25	÷		$-B/2A$	$\frac{\sqrt{4ac-B^2}}{2A}$	$-B$	$-B$		2A
26	$X \rightleftarrows Y$		$\frac{\sqrt{4ac-B^2}}{2A}$	$-B/2A$	$-B$	$-B$		2A

The numerators of the answers require two copies of the discriminant and two copies of $-b$. We already have two copies of $-b$, so press ENTER to produce another copy of the discriminant (13). We now change the sign of one of these discriminants since it may not be convenient to do so later (14).

Next we press R↑ to move a, $-b$ and a discriminant into position for addition (15). After addition (16), R↑ is pressed again to bring $-b$ and the negative discriminant into position (17). Then we add again (18).

R↑ is pressed three times to put the two numerators in X and Y and move junk to the top of the stack (19).

We now have a in the side register, but 2a is needed twice; therefore, we recall a (20), multiply by 2 (21), and store (22).

One of the answers is produced by dividing (23). The other numerator is positioned by pressing $x \rightleftarrows y$ (24). Next, we recall 2a which is used to divide the numerator (25). The display now shows one answer. To see the other, we simply press $x \rightleftarrows y$ (26).

This is the complete memory map for the real case. A data format must be decided upon for the complex case. If the answer is complex, it will be a complex conjugate pair. The two answers will be of the form $x + \sqrt{-1}y$ and $x - \sqrt{-1}y$. The real part will be in the X register and the imaginary part will be in the Y register. It turns out that the real part is $-b/2a$ and the imaginary part is $\sqrt{b^2-4ac}/2a$.

The memory map for the complex roots (**Table 3**) starts with the values we had in memory at the time the test for a negative discriminant was made (line 11 in **Table 2**).

The square root of the absolute value of b^2-4ac is needed. Since b^2-4ac is negative, press CHS (A), then $\sqrt{x}$ (B).

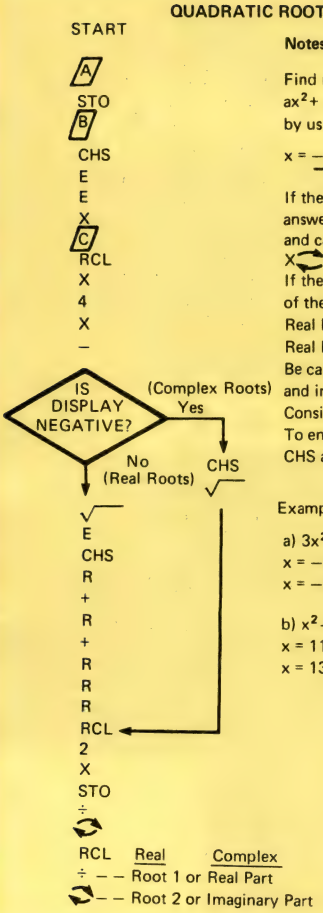
The two numerators are now in X and Y. Both need to be divided by 2a. This is exactly the same as in the real case. The rest of the algorithm uses the same keystrokes as the end of the real algorithm (resume at line 20). Check to make sure that the real and imaginary components are in the right places at the end of the algorithm.

The algorithm is now transcribed from the memory map (**Table 4**). Directions and examples are provided.

Nine hints for writing algorithms

1. Work out the equations you wish to solve with symbols. Break up the algorithm into several parts, if necessary, to allow as much use of memory as possible.
2. Try to arrange the input variables together in the beginning, and in a familiar order.
3. If possible, use repeated keystrokes. It is easier to press the same key three times than it is to press one key and then look for another.
4. Be sure to tell the user beforehand if he will need special values in the algorithm. To get near the end of an algorithm only to find that the calculator is needed to compute an input value is most frustrating.
5. Include an example so the user can try out an algorithm and know that it works.
6. Stay away from elaborate data formats, where different digits in a number mean different things.

QUADRATIC ROOTS ALGORITHM



Notes:

Find real and complex roots of:
$ax^2 + bx + c = 0$
by using the quadratic formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

If the roots are real, the two answers are in the X and Y registers and can be seen by repeatedly pressing X⇄Y.
If the roots are complex, they are of the form:
Real Part $+ \sqrt{-1}$ Imaginary Part
Real Part $- \sqrt{-1}$ Imaginary Part
Be careful not to confuse the real and imaginary parts.
Consider zero positive.
To enter a negative data value, press CHS and then key in the value.

Examples:

a) $3x^2 + 4x + 5 = 0$
$x = -0.6666666667 + \sqrt{-1}\ 1.105541597$
$x = -0.6666666667 - \sqrt{-1}\ 1.105541597$

b) $x^2 - 24x + 143 = 0$
$x = 11$
$x = 13$

Some of the advanced HP calculators use this format, but juggling digits is just too hard on an HP-35.

7. Work out the algorithm without special options first, then put them in later.
8. If you are expanding power series, look for values generated in low-order terms which appear in high-order terms. You can save computation if the entire term does not need to be computed each time.
9. If you are working with an alternating series and using hint 8 above, you can get the same effect as $(-1)^n$ by pressing CHS on the common term each time through the loop. ▭

Author's biography:

Lee Morin is a research engineer with the Massachusetts Institute of Technology Architecture Machine Group. Lee graduated from the University of New Hampshire with a B.S. in Math/Electrical Science and plans to enter New York University Medical School. He is a member of Tau Beta Pi and Pi Mu Epsilon.

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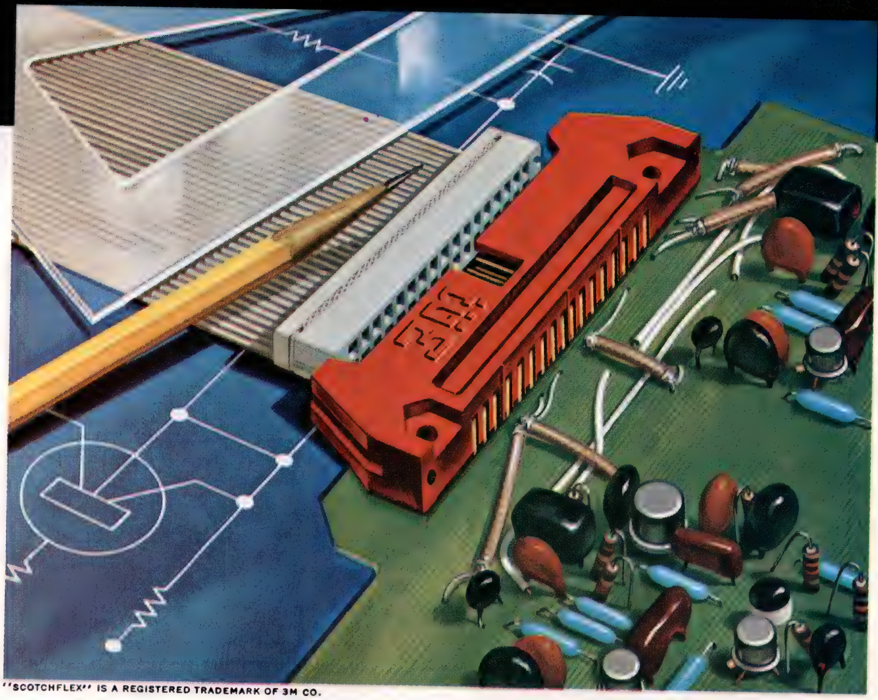

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Split-phase motor control accomplished with CMOS

Thyristor gating of narrow pulses provides a novel approach to motor control. Dc motors can be replaced with split-phase devices.

Vernon C. Gregory, Motorola Semiconductor Products, Inc.

If you're fed up with maintenance problems of brush infested motors, here's a design that uses low-cost brushless motors. The motor system interfaces directly with CMOS logic families, is reversible and can be dynamically braked.

The system uses a split-phase motor rotating CW or CCW, dependent upon which of the two direction-control triacs is conducting. The braking feature can stop most motor-load combinations in 0.1 sec and requires only a single SCR and two diodes.

Triacs provide economy

Traditional split-phase motor control uses switch closures to control directions. In the switch positions (**Fig. 1**), the current through the CCW winding lags the CW winding current and the motor turns in the CW direction. The opposite result occurs with the switch in the CCW position. When the 2-pole switch is in the center position, the motor coasts to a stop. In this position the motor can be dynamically braked by saturating it with dc current. This is accomplished by momentarily closing the brake switch.

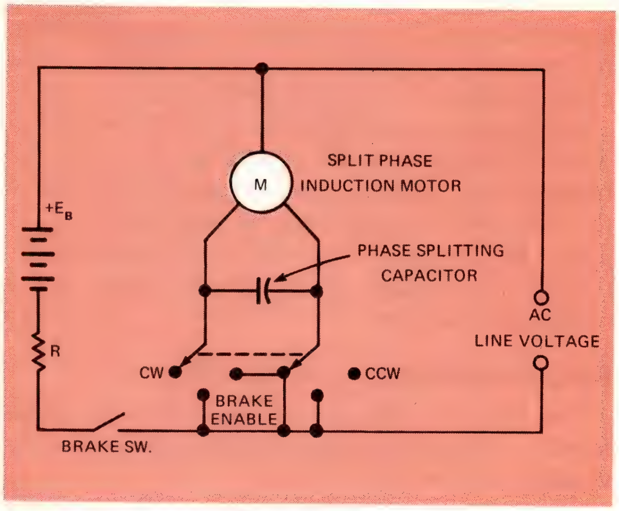


Fig. 1—Split-phase induction motor control with switches uses no triacs or SCR's to implement braking.

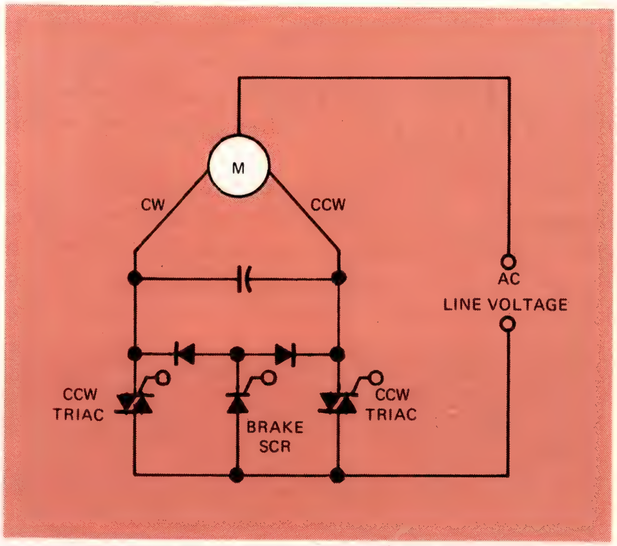


Fig. 2—Split-phase induction motor control with thyristors. Braking action is extremely strong and may be "gentled" by placing a resistor in series with SCR.

These same functions can be economically accomplished by thyristor devices (**Fig. 2**). The 2-pole switch is replaced by the CCW and CW triacs. Replacing the dc source and switch is an SCR and diode pair. Motor direction is determined by whichever triac is conducting. Braking is accomplished by turning on the SCR for the desired braking time.

Latching must be accomplished

A problem common with all thyristor circuits

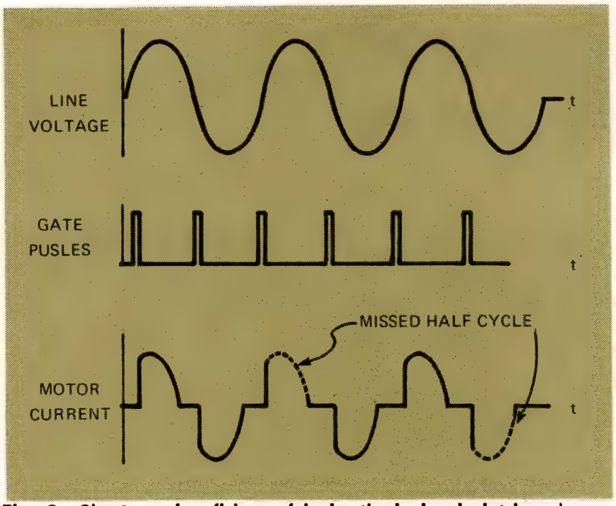


Fig. 3—Single pulse firing of inductively loaded triac shows retarding effect of current rise due to inductive loading. The latching current may not reach adequate level during the time gate current is flowing.

handling inductive loads is illustrated in **Fig. 3**. These thyristors have a minimum "latching current" that must be flowing in the device by the end of the gate pulse or they "pop out" of the conducting mode.

To avoid this problem use dc currents for gate signals. Isolation from the control logic though is difficult and expensive. One means of turning on thyristors with transformer coupling is to use large pulse widths. This requires relatively large

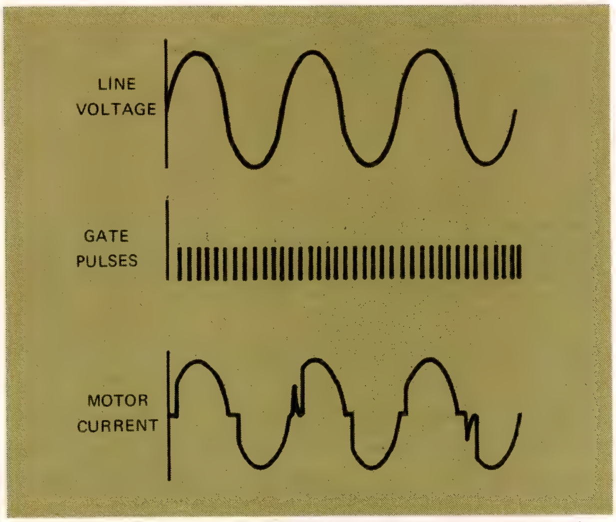


Fig. 4—Multiple pulse firing of inductively loaded triac provides adequate turn-on procedure for thyristor. Should turn-on not be accomplished on the first pulse, additional pulses will secure ON condition.

and expensive transformers, drivers and power supplies.

A satisfactory alternative is to supply many narrow pulses to the thyristor gates during each cycle. Such waveforms are shown in **Fig. 4**. Most SCR's and triacs turn on with 1 μsec gate pulses. A practical one for this type of service is a 5-μsec pulse with peak current equal to the worst case current required on the driven device's data sheet. Empirically a 100-mA gate current will turn on any thyristor up to a 35A rating. For many

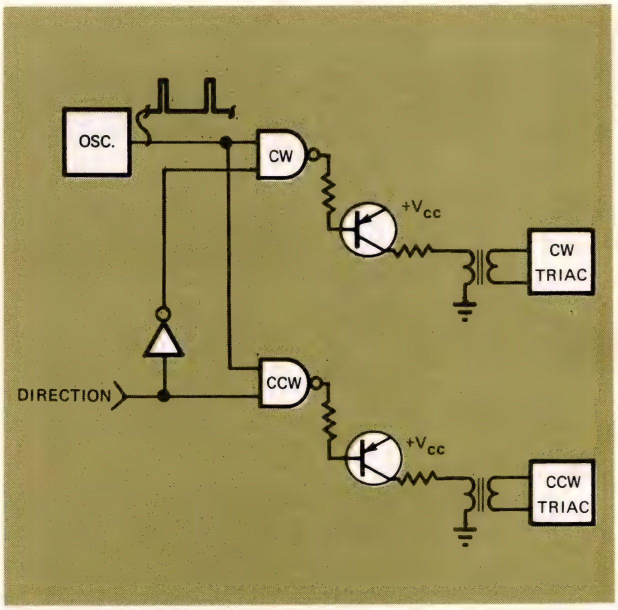


Fig. 5—Pulse steering direction control allows for either CW or CCW directions. Logic ONE = CCW and ZERO = CW.

applications a suitable stepdown transformer will allow the thyristor gate power to be sourced from a logic gate, rather than from a saturated switch.

Steering of narrow pulses from the oscillator to the triac is shown in **Fig. 5**. The main considerations here hinge on transformer characteristics. The brute force approach shown works without consideration for transformer saturation. The function of the collector resistors is simply to limit current should the transformers saturate.

An alternate approach lets the oscillator's pulse width control the peak transformer current. The transformers' primary inductance should allow the required current level to be reached in 5 μsec. The volt-second rating would be five times the supply voltage with an additional safety margin in volt-μsec.

Pulse transformer and CMOS

The final design uses a low-cost pulse transformer. The circuit works reliably on supply voltages of 5 to 15V.

Starting with a particular motor, the designer uses sensitive gate thyristors that allow him to drive these transformers directly from logic gates. It has been found that 100-mA gate current devices can be driven directly from CMOS logic on a 10V supply when special transformers are used. In this case a 5:1 step down ratio is employed with a primary inductance of 25 mH.

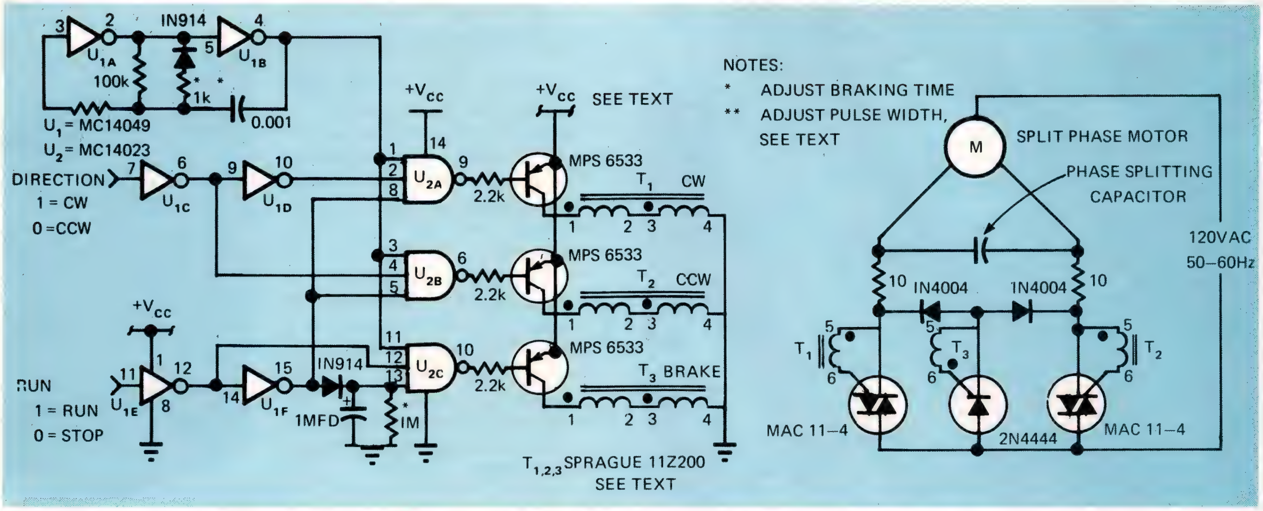


Fig. 6—Split-phase motor control rotates CW or CCW. This allows position servo functions to be realized when used with speed-reduction gear trains.

The complete system schematic is shown in **Fig. 6**. Inverter sections U_{1A} and U_{1B} comprise the oscillator. The 1k resistor marked ** adjusts the oscillator pulse width. In all cases this resistor should be selected so that the pulse transformers are not allowed to saturate.

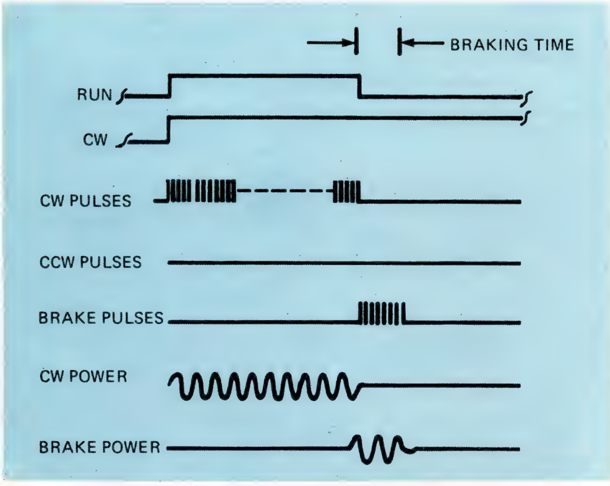


Fig. 7—Timing for a CW run sequence showing activation of brake for a short time at end of each RUN period.

The RUN input essentially enables the triac-selecting gates, while inhibiting the brake driving gate U_{2C}. The timing diagram is shown in **Fig. 7**. Brake duration is controlled by the 1 MΩ resistor marked * at the U_{2C} input. With the values shown, the brake is applied for approximately 1 sec. Should more gentle braking action be desired, a resistor may be placed in series with the SCR. Braking time required is a function of braking current and the motor's inertial loads. These motors are not generally designed for dc braking so respect must be paid to each motor's mechanical and thermal limitations.

10Ω resistors are placed in series with the triacs to prevent damage to them during fast reversing or "plugging," for when the motor is plugged, it is possible to discharge the phase splitting capacitor through the triacs. This would result in excessive "$\frac{di}{dt}$."

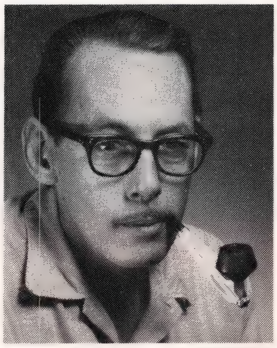
Precision control provided

The triacs and the SCR have been electrically configured so they may be mounted on a common heat sink. The heat sink is at the potential of one side of the ac line and should be isolated from other circuit elements and structure. In practice, driving small motors in intermittent service does not require a heat sink.

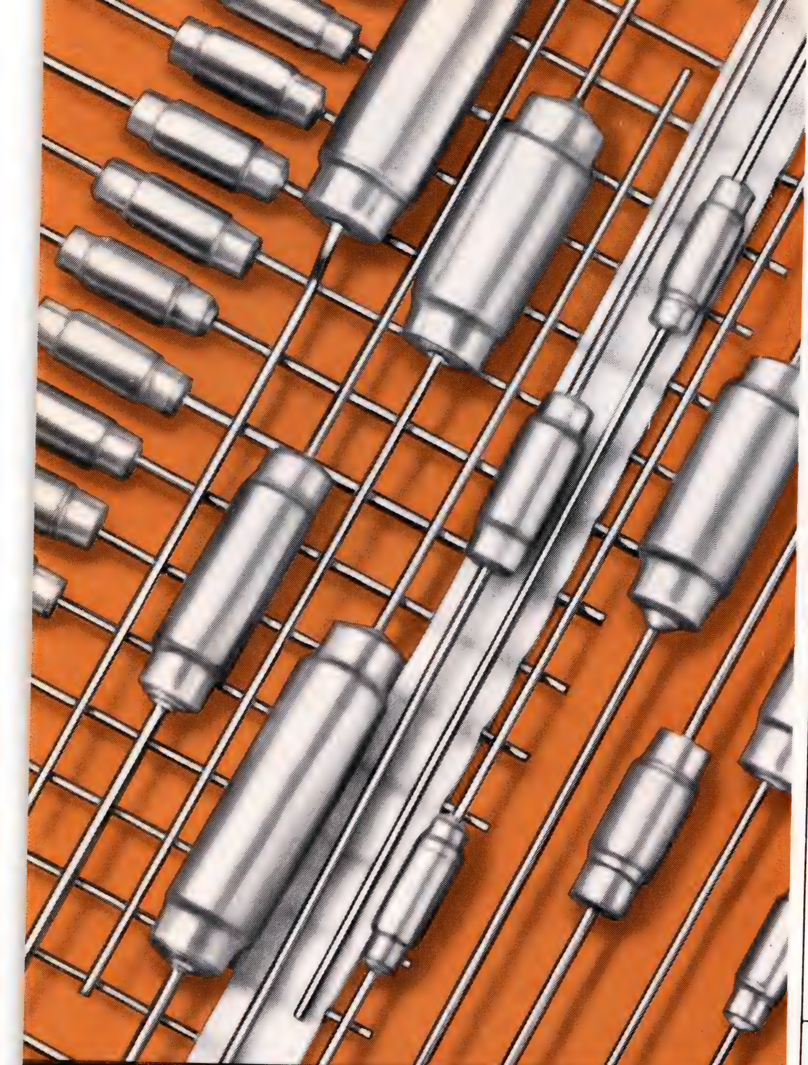
Shaft positioning servos employing this technique have been used to control ball valves and other throttling functions in process control. Usable with shaft position encoders, it generates feedback information, while overshoot and other stability problems easily are controlled by the strong braking function.

An important design feature is noise immunity, a result of the properties of CMOS. In numerous installations the control circuitry card has been mounted directly to motor frames and run without trouble in high noise environments. □

Author's biography



Vernon C. Gregory is an Industrial Systems Engineer at Motorola Semiconductor Product Inc., Phoenix, AZ, where he has been employed for nine years. Vernon received his degree in math from Arizona State Univ. He lives in Tempe, AZ, a place that affords him the opportunity to pursue his favorite hobby, desert rat.



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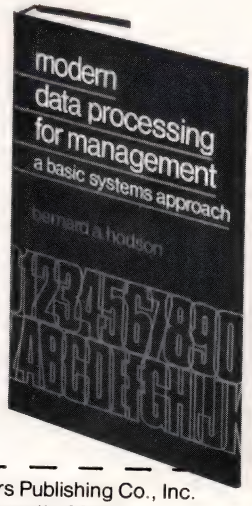

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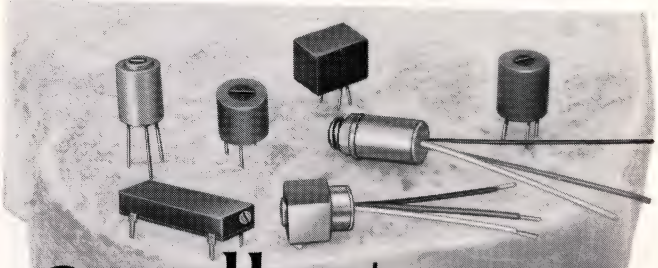

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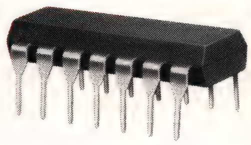

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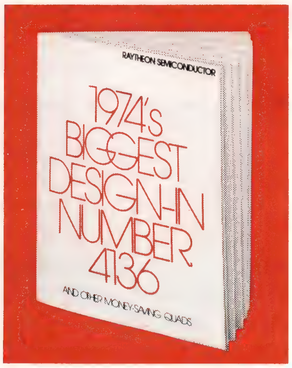

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EDN DESIGN AWARDS

Photocoupler makes an isolated threshold switch

Jim Cook
General Electric Co., Syracuse, NY

Are you faced with the problem of providing a threshold switching function to separate high level noise from switching signals? Do you also need electrical isolation between the signal sensing and the switching portions of the device? Then consider the photoisolator. A typical line-current sensing application might include these requirements:

1. Noise currents, on the line to be sensed, range up to 5 mA ($I_O \leq 50\ \mu A$ when $I_{IN} \leq 5mA$).
2. Operating currents to be sensed range as low as 10 mA ($I_O \geq 0.1\ I_{IN}$ when $I_{IN} \geq 10$ mA).
3. No more than a 2V drop can be tolerated for the sensor ($V_{12} < 2V$).
4. Operation is required over a −55 to +100°C temperature range.

A standard photocoupler (**Fig. 1**) programmed with a 150Ω, 1/2W, 5% resistor will do this job for signal pulses as short as 10 μsec, as will be shown.

Key to this circuit design is that the current-transfer ratio of a phototransistor coupler can be made practically nil at some arbitrary input current. It then can be changed rapidly back to 10% or more at a slightly higher level by the use of two biasing resistors. Shunt resistor R_1 (across the coupler input terminals) provides a current path to bypass the LED. A second resistor, (R_2), across the base-emitter terminals of the coupler reduces the low current gain of the phototransistor.

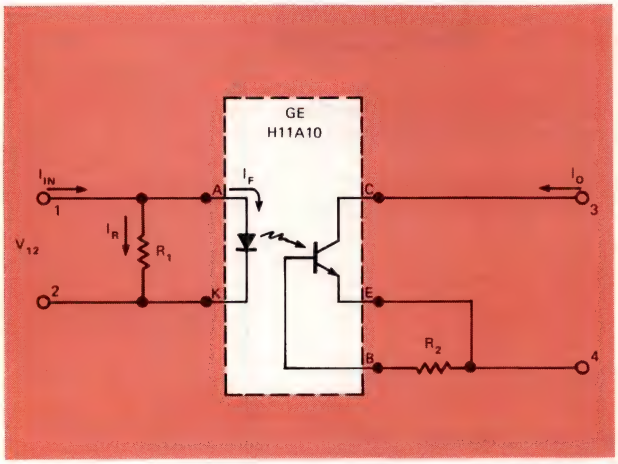

Fig. 1—Two resistors are all it takes. R_1 and R_2 allow the current-transfer ratio to be made practically nil at an arbitrary input current and then changed rapidly back to 10% or more at a slightly higher level. This gives you an isolated threshold switch.

A typical gallium arsenide LED V-I characteristic (**Fig. 2**) shows a sharp voltage threshold at about 1V. This threshold, being relatively stable with temperature, provides the basis for our current threshold.

If we assume that a 3 mA I_F will provide enough light to produce the required 1 mA (10% of 10 mA) in the output transistor, and that at an I_F of 3 mA the V_F of the diode is 1V, we can solve for R_1. It should shunt 7 mA when I_{IN} = 10 mA.

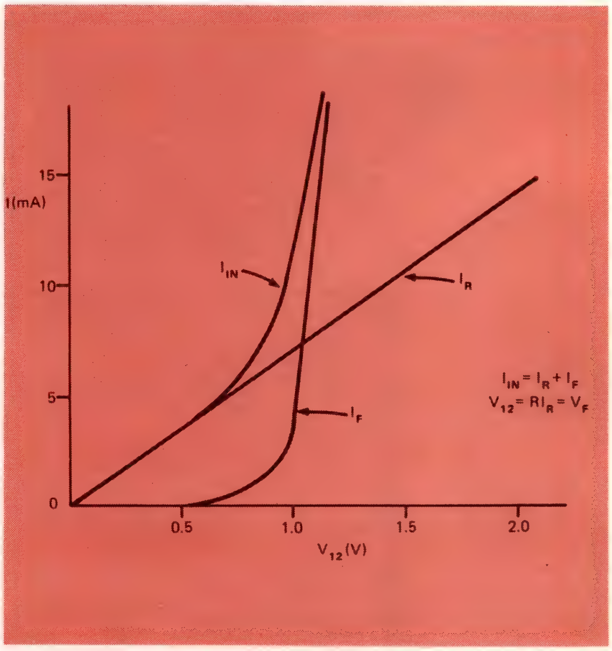

Fig. 2—Sharp, stable threshold of a typical gallium arsenide LED, that occurs at 1V, provides basis for circuit's current threshold.

For practical purposes, let's use a standard 150Ω, 5% resistor. Using this value and considering tolerance effects, the maximum forward voltage across

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the LED at the "OFF-state" condition (maximum input of 5 mA) is:

$$V_F = V_{12} = I_R \times R_1 = 5\text{ mA} \times 158\Omega = 0.79\text{V}$$

In **Fig. 2** we can see that when $V_F = 0.79$V, the forward current through the diode (and therefore its light output) is very low.

Output current I_O is composed of two elements; the light-induced current, dependent upon the current transfer ratio of the coupler; and the leakage current of the transistor. Since the amount of light from the LED is small in the "OFF-state" condition, we can say, $I_O = I_{CE}$ (light induced) + I_{CE} (leakage) $\approx I_{CE}$ (leakage).

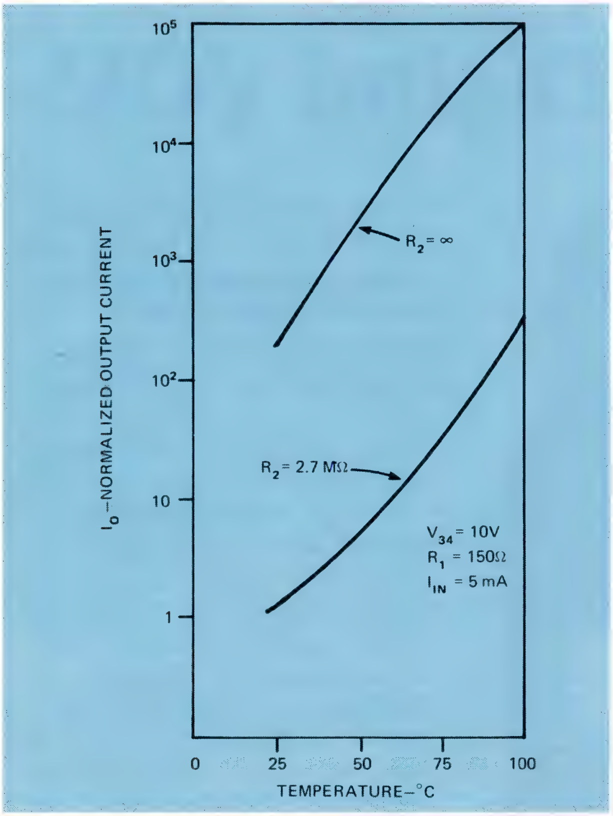


Fig. 3—R_2, the base-emitter resistor, should be small enough to reduce transistor gain at low levels, yet high enough so that "ON-state" gain is unaffected. Although a large range of resistors meets these requirements, effects of R_2 on the output current vs. temperature characteristics must be considered.

With the base of the transistor open, a leakage specification of 50 μA at 100°C would be difficult to guarantee. Typical phototransistor I_{CEO} at 100°C is in the 10 to 100 μA region. However, this leakage can be lowered orders of magnitude by the use of resistor R_2 between the base and emitter. This resistor inhibits the transistor's gain until the current through it allows the voltage to exceed V_{BE}. We would like a resistor low enough in value to reduce transistor gain at low levels, yet high enough so that gain in the "ON-state" condition is unaffected. A large range of resistors meets these requirements.

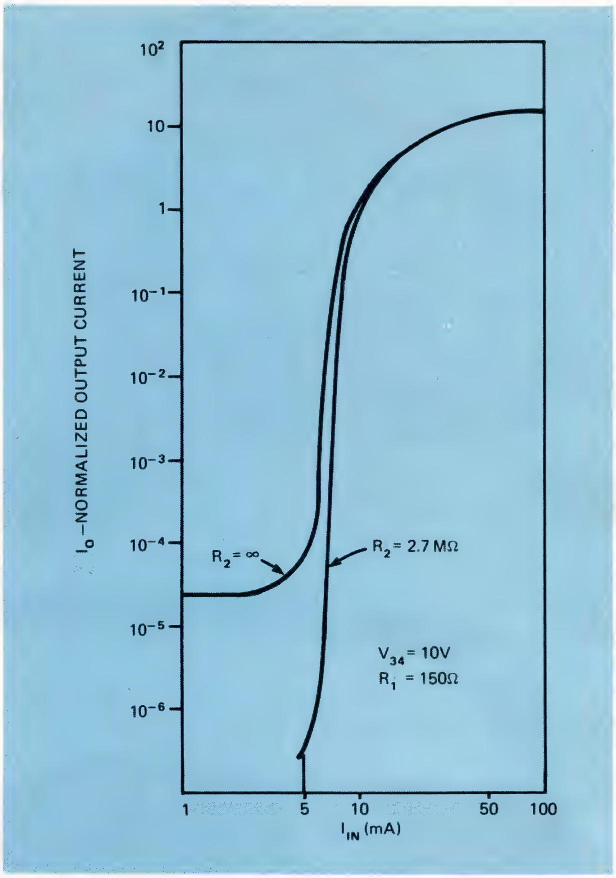


Fig. 4—Transfer characteristics (output vs. input current) vary with the value of R_2, as these curves show.

For example, choose 2.7 MΩ and assume a transistor gain of 500. With the 0.6V V_{BE}, we don't expect to see any transistor gain until the base current exceeds 200 nA. To get a 1 mA output, we need a 2μA base current, well above the 200 nA level. Effects of the 2.7 MΩ resistor are shown in **Figs. 3** and **4.**

Now consider I_O when $I_{IN} \geq 10$ mA. Again, $I_O = I_{CE}$ (light induced) + I_{CE} (leakage), since I_{CE} (leakage) is $< 50\ \mu$A.

$$I_O \approx I_{CE}\text{ (light induced)} = I_F \times \text{CTR}$$

where CTR is the current transfer ratio of the coupler.

Reviewing **Figs. 1 and 2,** using $R_1 = 150\Omega$, and imposing the requirement for a minimum of 1 mA output with $I_{IN} = 10$ mA, we can calculate a table of values indicating the parameter tradeoffs:

25° COUPLER TRADEOFFS				
I_{IN} (mA)	I_R (mA)	I_F (mA)	V_{12} (V)	MIN. CTR (%)
10	9	1	1.35	100
10	8	2	1.20	50
10	7	3	1.05	33
10	6	4	0.90	25

The table indicates the coupler must have either a low V_F or a high CTR or a balance between them.

Typical characteristic curves of phototransistor couplers indicate V_F increases and CTR decreases with decreasing temperatures. Considering this, and R_1 at the low end of its tolerance (142Ω), the coupler must meet a more severe set of parameters at −55°C.

−55° COUPLER TRADEOFFS		
I_F (mA)	MAX. V_F (V)	MIN. CTR (%)
1	1.27	100
2	1.13	50
3	0.99	33
4	0.85	25

The H11A10 photocoupler is characterized and specified using the 2-resistor approach to provide the threshold function. Changing the value of R_1 programs the threshold level (**Fig. 5**). □

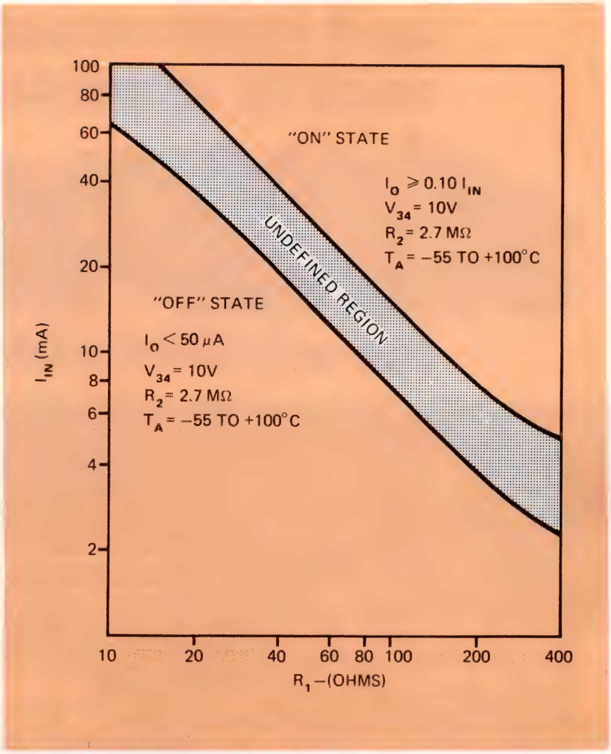


Fig. 5—R_1 programs threshold value. H11A10 is characterized and specified using two resistors to provide the threshold switch function.

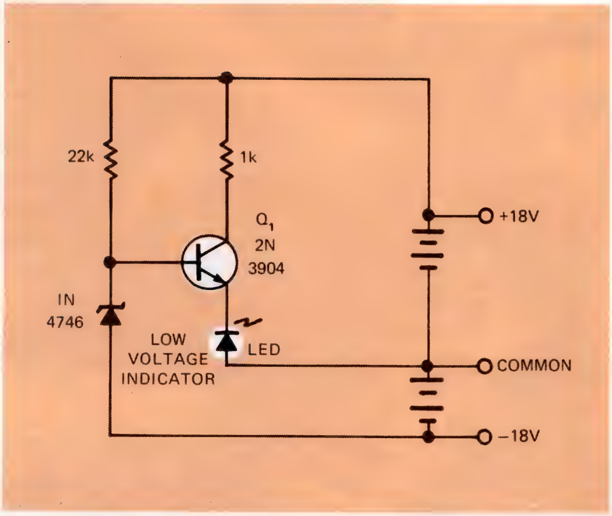
To Vote For This Circuit
Circle 150

Battery monitor is efficient, yet simple

Wm. Denison Y. Rich
AFCRL, Bedford, MA

This circuit signals a low voltage level on a ±18V battery pack and draws very little current in the standby mode.

The zener was chosen such that when it conducts, the base of Q_1 is held below Common and is reverse biased. When the overall pack voltage drops low enough, the zener loses control and Q_1 becomes forward biased. This turns on the LED or other signal device. Battery drain in the OFF mode is less than 1 mA. □



Zener conducts in OFF mode, reverse biasing Q_1, and limiting battery drain to 1 mA. When voltage drops, Q_1 conducts, lighting the warning indicator.

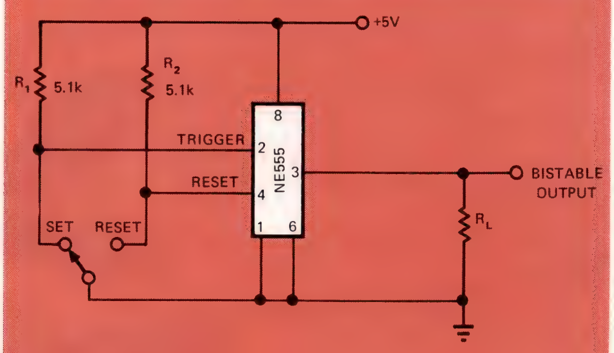
To Vote For This Circuit
Circle 151

Mini-DIP bistable flip-flop sinks or sources 200 mA

Russell L. Gephart,
Beckman Instruments, Inc., Palo Alto, CA

When you need a bistable flip-flop, but space requirements demand an 8-pin package, don't overlook the versatile 555 timer. By eliminating

the R-C timing network and tying the threshold low, output states are determined by the trigger and reset inputs. These inputs are pulled high through R_1 and R_2, then pulled low through either a switch or a TTL logic level ZERO.



TRUTH TABLE

TRIGGER (PIN 2)	RESET (PIN 4)	OUT
↓	HIGH	↑
↑	HIGH	HIGH
HIGH	↓	↓
HIGH	↑	LOW

A logic ZERO to the reset input (pin 4) will drive the output low. The output will remain low until the reset goes high and the trigger goes low. Due to this bistable action, contact bounce of a mechanical switch will not cause erroneous switching of the output.

In addition to the space gained by using an 8-pin package, the NE555 will source or sink 200 mA. □

To Vote For This Circuit
Circle 152

Readers have voted:

Robert Liebman winner of the April 20, 1974 U.S. Savings Bond Award. His winning circuit is "Single diode compensates IC oscillator." Mr. Liebman is with Dytron Electronics, Flushing, NY.

Design Entry Blank

$20 Cash Award for all entries selected by editors. An additional $50 U.S. Savings Bond Award for winning circuit each issue, determined by vote of readers. Additional $1000 Bond Award for annual Grand Prize Circuit, selected among semi-monthly winners by vote of editors.

To: Design Award Editor
EDN
Cahners Publishing Co., Inc.
221 Columbus Ave., Boston, MA 02116.

I hereby submit my entry for EDN's DESIGN AWARD PROGRAM.

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Company___________________________

Division (if any)_______________________

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Circuit Title_________________________

Print full name (no initials) and home address on lines below for mailing of your bond if chosen monthly issue winner. Also, please include your Social Security number.

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Entry blank must accompany all entries. Circuit entered must be submitted exclusively to EDN, must be original with author(s), must not have been previously published (limited-distribution house organs excepted), and must have been constructed and tested.

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In submitting my entry, I agree to abide by the rules of the Design Award Program.

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Your vote determines this issue's winner. All circuits published win $20 cash. All issue winners receive an additional $50 U.S. Savings Bond and become eligible for the annual $1000 U.S. Savings Bond Grand Prize.

Vote now, by circling the appropriate number on the reader inquiry card.

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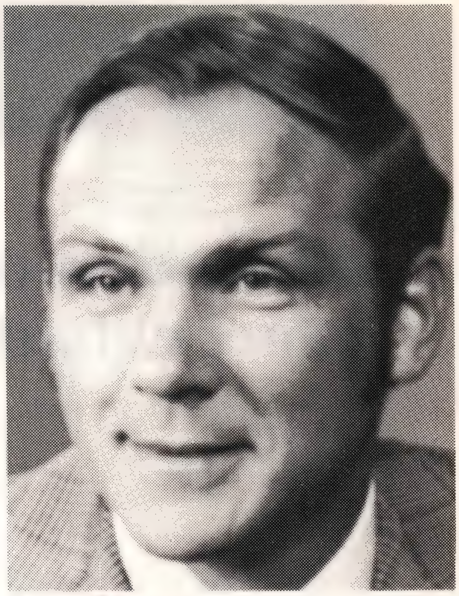

Robert Shevlot,
Vice President Marketing

Texscan Corporation, 2446 North Shadeland
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But we've found we may have grown complacent. Complacent in telling you about a complete product line. That's the reason for this ad.

No one, but no one, has Texscan's line-up and range of sweep generators, oscilloscopes and spectrum analyzers.

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Sweep/Signal Generators

Model	Frequency Range	Sweep Width	Price
VS—20	500 Hz to 25 MHz	500 Hz to 25 MHz	$1,495.00
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Model	Frequency Range	Sweep Width	Price
VS—90B	5 MHz to 2350 MHz	100 kHz to 1100 MHz	$2,695.00
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WB—713	1 to 960 MHz in 2 bands	Band 1: 0.1 to 500 MHz Band 2: 0.1 to 500 MHz	$ 995.00

In this day of shortages we have certain items on the shelf for jet delivery.

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For more information, Circle No. 40

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All models of DPM family take same panel cutout and connector wiring

PROGRESS IN DPM'S

Nearly everyone who has employed digital panel meters knows that different models seldom are physically interchangeable. Often the panel cutout and space needed behind the panel differ, and equally often the connector wiring isn't the same.

Now Gralex Industries offers a solution in its Series 37 units.

DPM family, with models from 2-1/2 to 3-3/4 digits, provides complete interchangeability through common panel cutout, case dimensions and connector wiring.

These span a broad spectrum of OEM applications, and include models with 2-1/2, 2-3/4, 3-1/2 and 3-3/4 digits. All employ pMOS LSI, fit the same panel cutout, require identical space behind the panel and have the same connector wiring.

Because of this uniform relationship, a designer can change from one model to another at any time without costly rework or redesign. He won't be locked in by the initial DPM choice, but instead can offer his customers options that embrace various ranges, resolutions and input powering. Equally important, the additional cost, if any, is small.

Available input F.S. ranges span from 199 mV through 39.99V, with accuracy specified as 0.5% of reading for the 2-1/2 and 2-3/4-digit models and 0.1% for the 3-1/2 and 2-3/4-digit ones. All models indicate overrange by blanking the display and illuminating a set of dashes. No input overload is ever displayed as a numerical value.

Both Beckman half-inch 7-segment planar gas-discharge readout digits and one-third inch 7-segment LED ones are standard, giving further flexibility. Models are offered for powering from 100, 117 or 220V line or 5V battery.

An unusual feature of the Series 37 DVM's is the small price differential added by going from 2-1/2 or 3-1/2-digit models to 2-3/4 or 3-3/4 ones. Also, both power and space have been provided for packaging additional circuitry within each meter. Finally, fully buffered and optically-isolated BCD outputs are available as an option.

As little as $89(100) buys a 3-1/2-digit bipolar model.

Gralex Industries, 155 Marine St., Farmingdale, NY 11735. Phone(516)694-3607.

Circle No. 140

LSI technology provides microcoded ROM firmware to manage very large RAM minicomputer memories

PROGRESS IN MINICOMPUTERS

A new "dynamic mapping" memory-management scheme (DMS) has been devised by Hewlett-Packard for its user-microprogrammable 4k RAM semiconductor memory minicomputers. DMS enables these 16-bit-word mini's to address large memories with no degradation of memory cycle time. In fact, a million-word memory could be accommodated, and the company is willing to quote on such models.

Accounting for the compactness and low prices of these new large-memory models, Hewlett-Packard cites features common to the whole 21MX line. They include low-cost 4k RAM memory and fast, infinitely-flexible plug-in firmware instructions. For example, all 25 of the DMS instructions, that manage memories up to a million words and give read/ write protection on an individual

Fast and easy... MOSTEK's MK4102-6 static 1K RAM.

275 ns!

MOSTEK's MK4102P-6 is fast—275 ns access time! But speed is only one of its features. Just as important, it's easy to use, requiring only one +5 V power supply. All inputs are TTL compatible. And the processing technology is strictly state-of-the-art utilizing a combination of N-channel silicon gate plus ion implantation.

Also, you can accomplish large memory array construction with a minimum of additional circuitry because of the high impedance "off state" coupled with "chip select" input.

What else? Well, the MK4102P-6 is a pin - for - pin alternate for the 2102. But there's no comparison in access time. Check for yourself.

MOSTEK's line of 1K RAMs gives you plenty to select from, static or dynamic. They range from the MK4008-9 (at 800 ns) through two other versions of the MK-4102 (450 ns or 1 μ sec) up to the popular MK4006 (at 400 ns). Check the table below for the part number you need.

When your design requires an MOS memory, remember MOSTEK. Call your nearest MOSTEK distributor or representative or contact MOSTEK, 1215 W. Crosby Road, Carrollton, Texas 75006, (214) 242-0444. In Europe contact MOSTEK GmbH, TALSTR. 172, 7024 Bernhausen, West Germany, Tel. 798038.

MOSTEK®

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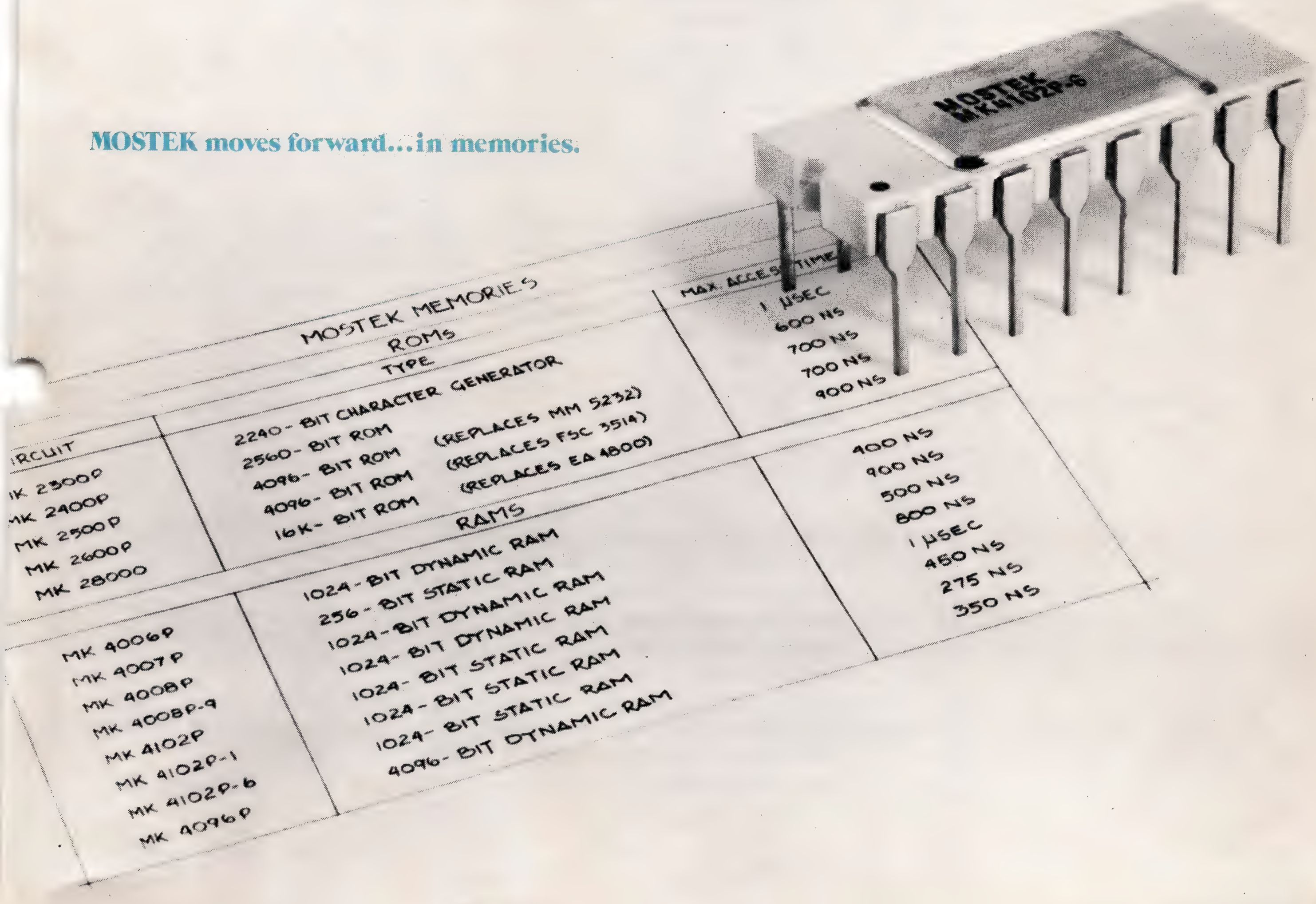
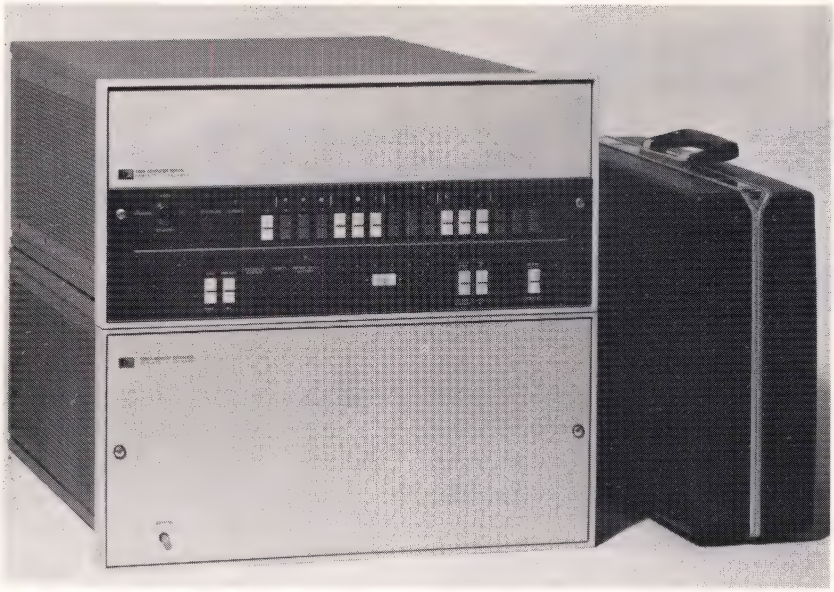
MOSTEK moves forward...in memories.





The 196,608 16-bit word Hewlett-Packard 21MX minicomputer is only 17-in. high.

1k-page basis, are in microcode on half of a single small circuit board.

These large-memory versions of the H-P 21MX mini's retain the 650-nsec speed and all the latest features of the earlier models. Now standard are user-microprogrammability, parity, floating point, extended arithmetic unit and brownout-proof power supply. Optional features to speed-up Fortran and assembly language programs are also available. They too come as low-cost plug-in firmware adding double-precision arithmetic, subroutine and array addressing (OEM quantity of 50—$495). All capabilities are field-retrofittable.

Firmware: hi-speed key

The DMS functions with main memory somewhat as "virtual memory" schemes function with disc memory. DMS allocates memory dynamically, under supervisory program control.

HP's DMS expands the address space from 15 bits to 20 bits, hence the ability to manage a million-word memory. The most-significant five bits of the standard 15-bit address bus are used to select one of 32 high-speed registers in the DMS hardware. Each register points to one of a possible 1024 pages (each of 1024 16-bit words) and also provides two bits of read/write information for that page.

Four independent and dynamically-alterable 32-register blocks are assigned as the "maps" of the DMS. Two maps configure memory for program execution (one for the system and one for the user) and two are assigned to the dual-channel port controller for direct memory access operations. By structuring the processor with separate buses for data and addressing, and using high-speed microcoded routines, the translation done by the DMS is completely transparent to the memory cycle. Thus 650-nsec cycle time is preserved.

The 25 microcoded instructions in DMS firmware, including cross-map moves and block transfers, give extensive control over memory allocation and read/write protection. Complete control over DMS function is available through user microcode. Thus, the user can add his own unique memory management and protection instructions, to optimize his particular system design.

Now infinite expansion

With independent selections of two processor mainframes, an I/O extender chassis and a variety of memory cards, H-P 21MX mini modules can be combined in many ways. But further enhancement now is available by the introduction of the DMS memory-management plug-in firmware and a 12990A Memory Extender chassis.

The smallest processor mainframe, the 5-1/4-in.-high M/10, has space for a maximum of 32,768 words of 4k RAM semiconductor memory and four powered I/O channels.

The 8-3/4-in.-high M/20 processor mainframe can contain 65,536 words of memory, the new memory management cards and nine powered I/O channels.

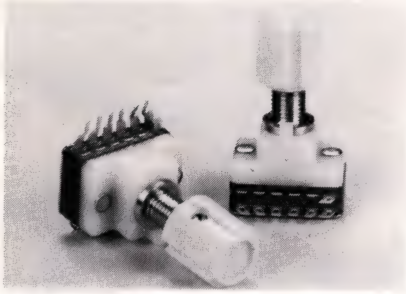
Massive memory size is now easily available with the 12990A Memory Extender chassis. However, no further controllers are required. The chassis is 8-3/4-in. high and can accommodate as many as eight plug-in semiconductor memory boards. Each LSI-MOS board is designed for 16,384 16-bit words. Thus augmented, the H-P 21MX, with its M/20 processor memory of 65,576 words, would provide a maximum of 196,608 16-bit word memory!

Price and delivery

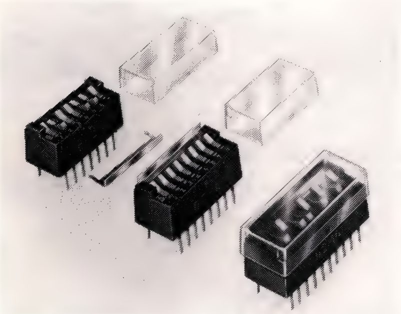
On an OEM quantity-50 basis, price of the 65,536-word 21MX, contained in a single 8-3/4-in. high cabinet, is $17,358. On the same basis, but occupying two 8-3/4-in. cabinets, a 131,072 word is $31,812 and a 196,608-word version, $43,956. First customer deliveries are scheduled for February.

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. Phone(415)493-1501

Circle No. 141

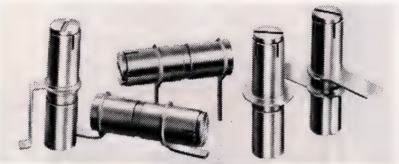


SQUARE SUBMIN. ROTARY SWITCH PLUGS IN PC BOARD. Only 9/16-in. across the body and 13/16-in. max. width across terminals, the Series 80 has pc pins on standard 0.100-in. centers. Initially 30°, 60° and 90° index angles will be available and the enclosed design includes lifetime lubrication for 50,000 cycles. < $2.00 (1000). Production in Dec. Stackpole Components Co., Box 14466, Raleigh, NC 27610. Phone(919)828-6201. **Circle No. 170**



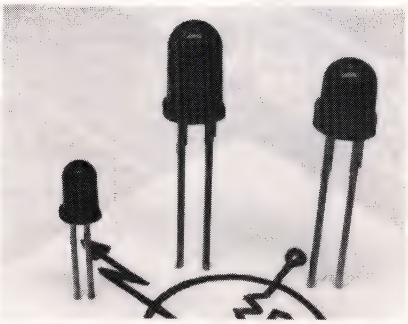
DIL PROGRAM SWITCHES HAVE PLASTIC COVERS, LOCKING BAR. Operation of separately-detented rocker actuators makes or breaks each circuit independently. A locking bar prevents accidental programming changes and an ON marking identifies which circuits are open or closed. Models are offered with 7, 8 or 10 spst switches/module. Rating is 100 mA@5V dc and 25 mA@24V dc. Min. life expectancy is 5000 operations. Model DS-7, $2(500). Alco Electronic Products, Inc., 1551 Osgood St., North Andover, MA 01845. Phone(617)685-4371.

Circle No. 171

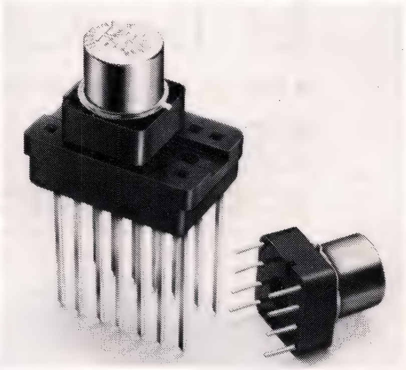


EXTENDED RANGE HIGH-FREQUENCY TRIMMERS ARE SOLDERLESS. Four series of Giga-Trim capacitors provide greatly increased capacitance ranges. The 7260-4 Series (0.21-in.L×0.07-in.dia.) has a range of 2.5 to 5 pF. Also available are the 7270-4, 7280-4 with intermediate ranges, and the 7290-4 Series (0.56-in.L×0.12-in.dia.) with adjustment range of 7 to 30 pF. All are available in 5 mounting styles. $4.60(1000). Johanson Manufacturing Corp., 400 Rockaway Valley Rd., Boonton, NJ 07005. Phone(201)334-2676.

Circle No. 172



RESISTOR LED LAMPS NOW IN 4 COLORS, 2 VOLTAGE RATINGS. The series includes 3 plastic lens styles in red, green, yellow and orange—for either 5 or 12V dc operation. Each contains an integral current-limiting resistor in series with the LED chip and is rated for luminous intensity at 16 mA. There are 100 red, 33 each of yellow and green and 31 orange lamps offered. Resistor LED's are 50¢(red), 60¢ other colors(1000). Xciton Corp., Shaker Park, 5 Hemlock St., Latham, NY 12110. Phone(518)783-7726. **Circle No. 173**



DIP SPREADER PADS MAKE TO-5 RELAYS MORE USEFUL. Offered with Teledyne's MIL and commercial TO-5-cased relays, these are spaced for standard DIP pinout of 0.300-in. grid by 0.100-in. spacings. With them, TO-5 relays can be directly inserted and soldered to standard grid pc boards. Or, they can be plugged into 14- or 16-pin DIP sockets as well as panels of the Augat, or similar type. Teledyne Relays, 3155 W. El Segundo Blvd., Hawthorne, CA 90250. Phone(213)973-4545.

Circle No. 174

PROGRAMMABLE PHOTOCOUPLER ISOLATES, SEPARATES NOISE. Type H11A10 "turns on" a transistor when input current exceeds a tightly-specified threshold. This threshold may be programmed over a 10:1 range (4-40mA) by changing one resistor. The H11A10 is characterized and specified with 2 resistors, one each in input and output. Isolation is 1500V and min. current transfer ratio is 10% in the ON state. To $1 in quantity. General Electric Co., Electronics Park, Bldg. #7, Mail Drop 49, Syracuse, NY 13201. Phone(315)456-2021.

Circle No. 175

BUILT-IN HEAT SINK INCREASES BRIDGE RECTIFIER RATINGS. Only 3/4-in. in diameter, yet rated for 10A, the H-FB Series anchors internal components by means of a retaining ring. Thus, they do not float in the plastic encapsulating material. Max. case temperature is 150°C, and max. 1-cycle surge current is 240A. Normally stocked as standard silicon avalanche devices, they also can be supplied as 200-nsec fast-recovery devices. $1.98 to $3.01(1000). Sarkes Tarzian, Inc., Semiconductor Division, 415 N. College Ave., Bloomington, IN 47401. Phone(812)332-1435. **Circle No. 176**

DIGITAL PUSHBUTTON POT PROVIDES 0.1% REPEATABILITY. Model 3680 KNOBPOT[R] combines a precision incremental decade potentiometer with an easy-to-read digital display, and fast, pushbutton resistance selection—all in a snap-mounting unit. Each decade has a rated life of 100,000 operations. Cermet resistance elements with 2W rating and 100 ppm/°C T.C. are offered from 5 kΩ to 1 MΩ ± 1%. $23. Bourns, Inc., 1200 Columbia Ave., Riverside, CA 92507. Phone(714)684-1700. **Circle No. 177**

Here's how we tested our 42,386th multimeter.

The world's best-selling 3½ digit multimeter is virtually indestructible.

Recently, two Fluke quality control engineers wanted to know if our 8000A 3½ digit multimeter would survive a fall from a 24-foot rack. We were shipping several to a phone company.

So they tossed one out the window. Two stories up. It still worked.

But 99 44/100% of these out-of-the-ordinary tests we **don't** instigate.

They just seem to happen.

Our president talks about the time he picked up an 8000A at a trade show without knowing it was ready for case removal. The works crashed to the floor but it still played perfectly . . . to everyone's delight and the president's relief.

One reason why our DMM is so tough: it only has 99 parts. Major analog and digital circuitry are on LSI chips.

It's also flexible. This DMM has 26 ranges, including five ranges of ac and dc volts, five ranges of ac and dc current, and six ranges of resistance. And it's the only DMM using an A-to-D converter with inherent self-zeroing to completely eliminate offset uncertainty.

But it's the ruggedness that really makes the 8000A a conversation piece. Our sales force still laughs about the Fluke salesman who was so hot to make a sale that he took his Fluke multimeter and brought it down—crash!—right on his prospect's desk.

"See," he said, "it's really tough."

And so it was, but the op amp that was hidden under a pile of papers wasn't. P. S.—our salesman didn't make the sale.

On a more positive note, a UPS truck accidentally backed over an 8000A not long ago . . . without ill effect.

So there you are. The world's largest selling 3½ digit DMM. And the toughest. And for $299 it could be yours.

For data out today, dial our toll-free number, 800-426-0361

In the continental U.S., dial our toll free number 800-426-0361 for the name and address of your nearest local source. Abroad and in Canada, call or write the office nearest you listed below, John Fluke Mfg. Co., Inc., P.O. Box 7428, Seattle, Washington 98133. Phone (206) 774-2211. TWX: 910-449-2850. In Europe, address Fluke Nederland (B.V.), P.O. Box 5053 Ledeboerstraat 27, Tilburg, The Netherlands. Phone 013-67-3973. Telex: 844-52237. In the U.K., address Fluke International Corp., Garnett Close, Watford, WD2 4TT, England. Phone 0923-33066. Telex: 934583. In Canada, address ACA, Ltd., 6427 Northam Drive, Mississauga, Ontario. Phone 416-678-1500. TWX: 610-492-2119.

FLUKE ®

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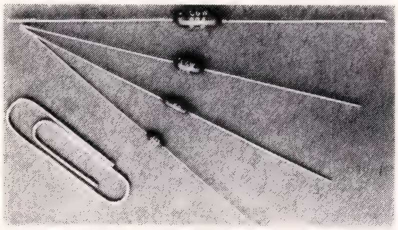
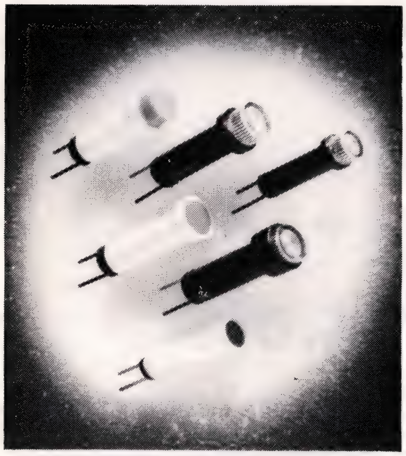


AXIAL-LEAD CERAMIC CAPS ANSWER AUTOINSERTION NEEDS. These conformally-coated "spin-seal" components can be made at high speeds while closely controlling uniformity and performance. Capacitance ranges are from 0.027 to 0.47 μF at 50V and from 0.001 to 0.22 μF at 100V, with ±20% or +80, −20% tolerances. Lengths range from 0.19 to 0.42 in., while diameters run from 0.1 to 0.145 in. Corning Glass Works, Corning, NY 14830. Phone(607)974-9000.

Circle No. 182



HIGH-BRIGHTNESS GaP LED'S COMPETE WITH INCANDESCENTS. These LED panel lights, run at 20 mA, compare favorably with a 60 mA incandescent lamp (type 683). They are rated at 2.5 mcd at 10 mA and all colors are available at the same price. There are numerous options on mounting, lenses and terminals. $1.10 to $1.31 (1000), depending on voltage and current ratings. Data Display Products, 5428 W. 104th St., Los Angeles, CA 90045. Phone(213)641-1232.

Circle No. 183

AUDIBLE ALARM SIGNAL GENERATES BOTH TONE AND BEEP. Using logic-level control for generating tone or beep modes at digital levels, Model AL-175 fits many digital and computer applications. The tone is a shrill 2600-Hz sound at high level. No RF noise is generated. The alarm withstands extreme humidity, vibration, altitude and salt spray. Floyd Bell Associates, 555 Marion Rd., Columbus, OH 43207. Phone(614)443-7427.

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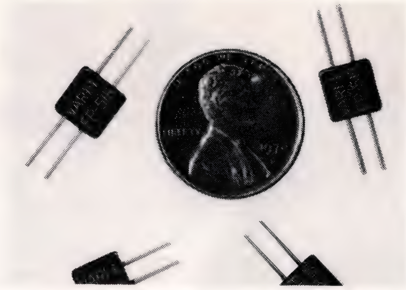

TINY WIDEBAND TRANSFORMERS FOR MIC SUBSTRATE USE measure only 1/4×1/4×1/8-in. They are available in balanced and unbalanced configurations with easily solderable or weldable planar ribbon leads. Other features are 0.5 dB insertion loss, > 1-GHz bandwidth, psec risetimes and linear group delay. Vari-L Co., 3883 Monaco Pkwy., Denver, CO 80207. Phone(303)321-1511.

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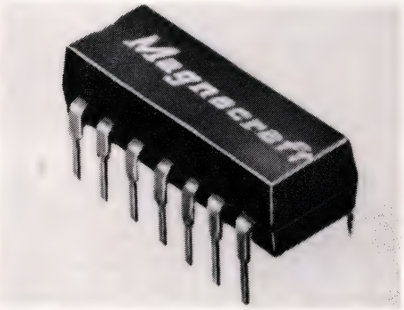
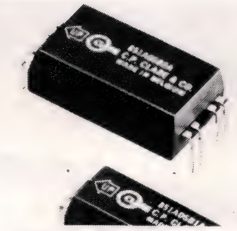


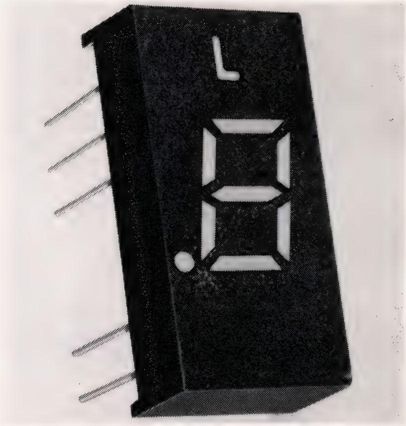
DIP RELAY HANDLES 120V RMS (OR 200V DC) SWITCHING. The Class 171VDIP dry-reed relay offers triac triggering, and compatability with DTL and TTL—with total isolation of the IC. This relay is available in 1 Form "A" contact arrangements with coil voltages of 5, 6, 12 or 24V dc. All versions are offered with a choice of internal clamping diodes and 8 or 14-pin models. Magnecraft Electric Co., 5575 N. Lynch Ave., Chicago, IL 60630. Phone(312)282-5500.

Circle No. 186



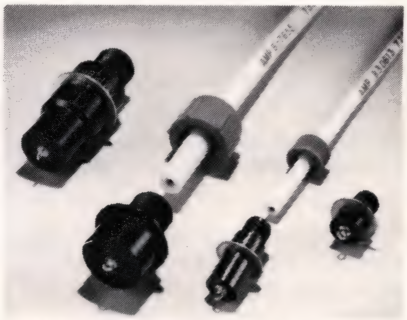
NOW: MERCURY-WETTED REED RELAYS IN A PCB PACKAGE. Miniature units, packaged in 1-pc. molded epoxy cases, easily withstand wave soldering and immersion cleaning. The 851 Series includes 1, 2, 3 or 4 Form-A contacts in 5, 12 or 24V dc coil ratings. All models feature 50-VA contact ratings, 3-msec operating and release time with bounce-free operation and life expectancy to 1×10^9 operations at signal levels. From $5.95 to $12.60. C.P. Clare & Co., 3101 W. Pratt Ave., Chicago, IL 60645. Phone(312)262-7700.

Circle No. 187



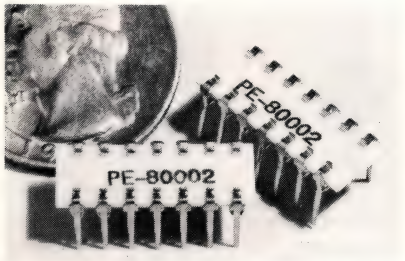
COMMON-CATHODE 0.3-IN. RED LED DIGIT HAS LEFT DECIMAL. The DL-702 has typical luminance of 0.7 mcd at 10 mA/segment. Satisfactory luminance may be obtained at an average current of 5 mA/segment when pulsed under narrow duty-cycle conditions. Light-pipe construction spreads illumination evenly over broad segments. Its package is a standard 14-pin DIP. $2.35 (1000). Litronix, Inc., 19000 Homestead Rd., Cupertino, CA 95014. Phone(408)257-7910.

Circle No. 188



GLASS-EPOXY RECEPTACLES HANDLE HIGHER VOLTAGES. Less expensive, and with a smoother, less-abrasive finish, these have a 66% higher voltage rating than their ceramic counterparts. Models with 10A capacity are available in 10, 15, 20, 25, 30, 40 and 50 kV dc sizes. They require no derating up to 70,000 ft. AMP Capitron Div., Elizabethtown, PA 17022. Phone(717)367-1105.

Circle No. 189



MULTI-USE "OPTION BLOCKS" FACILITATE INTERCONNECTIONS. Available in standard 14 and 16-pin ceramic DIP packages, they can serve for microprogramming, breadboarding, busing, inductance zeroing, prototyping, circuit shorting and trouble shooting. Also, by using them for single or multiple circuit interconnections, the need for jumper wires is minimized. Altering the interconnect pattern can be accomplished by simply changing option blocks. Pulse Engineering Inc., Box 12235, San Diego, CA 02112. Phone(714)279-5900.

Circle No. 190

LOW-COST 3/8-IN.[2] CERMET TRIMMERS HAVE 0.5W RATING. These single-turn units are only 0.187-in. deep and are available in 8 different pin arrangements for wave soldering on pc boards. Standard resistance values from 10Ω through 2 MΩ, rated at 0.5W at 70°C, are available. T.C. of R. is ±100 ppm/°C max. A multi-finger brush contact insures low contact resistance variation and excellent setting stability characteristics. 60¢(100). Weston Components, Archbald, PA 18403. Phone(717)876-1500.

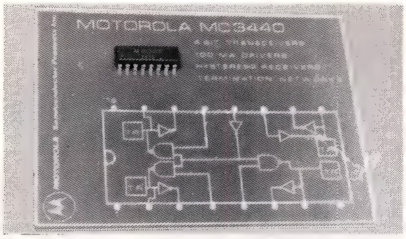
Circle No. 191

GREEN AND YELLOW GaAsP LED'S DELIVER 1.5 MILLICANDELAS. Operation at 10 mA gives typical brightness. Max. rating for these T-1 packaged lamps is 112 mW (40 mA continuous forward current). Either 521-9206 (green) or 521-9207 (yellow) sells for 55¢(1000). Dialight, 203 Harrison Pl., Brooklyn, NY 11237. Phone(212)497-7600.

Circle No. 192

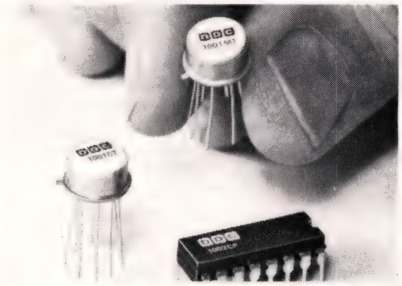
ADJUSTABLE CARD GUIDE ACCEPTS 3 TO 5-IN. CARDS. Made of glass-filled nylon, No. 8840-3 allows fast, easy mounting even when mounting holes are not perfectly aligned. Support is equivalent to that of 1-piece guides. Operating temperature range spans from −55 to +105°C. Cards from 0.55 to 0.70-in. thick can be accommodated. 20¢(1000). Thermalloy, Box 34829, Dallas, TX 75234. Phone(214)243-4321.

Circle No. 203



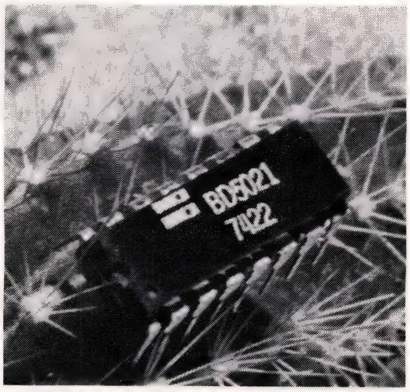
GENERAL-PURPOSE INTERFACE BUS STANDARDIZES INTERCONNECTIONS. Designed to conform to the standards being established by the IEEE, these DIP's permit the bidirectional flow of digital data between various instruments. The quad transceivers (MC3440, 3441 and 3443) feature receiver input hysterisis for noise rejection and open-collector driver outputs for wired-OR connections. TTL drive level and internal termination resistors are common in MC3440 and MC3441. $2.15 (100-999). Motorola Inc., Semiconductor Products Div., Box 20912, Phoenix, AZ 85036. Phone(602)244-6900.
Circle No. 193

SOS/CMOS LOGIC FAMILY REPLACES 4000 SERIES. Designed to replace bulk silicon CMOS, this series features high speed capability. Typical of this family is the INS4024E, a 7-stage binary counter. The counter operates at a min. guaranteed frequency of 10 MHz at 10V. All SOS/CMOS products are dielectrically isolated preventing 'latch up' failures common in SCR's. Available in plastic. INS4016E $1.08 (1000), INS4024E $2.02 (1000). Inselek Inc., 743 Alexander Rd., Princeton, NJ 08540. Phone(609)-458-5102. **Circle No. 194**



FET OP AMP FEATURES LOW INPUT CURRENTS. The 1001 and 1002 series offer high slew rates (6V/μsec) and common-mode rejection. Input bias is typically 2 pA. The 1002 series includes 2 1001-type amps in a single package. The 1001 series is packaged in a TO-99 can, while the 1002 is available in a 16-pin ceramic or plastic DIP. Price of the 1001 is $4-$50 depending upon offset voltage; the 1002 series ranges $6-$20. ILC Data Device Corp., Airport International Plaza, Bohemia, NY 11716. Phone(516)567-5601. **Circle No. 195**

FOUR TIMERS ON A CHIP REDUCE SYSTEMS COST. Two highly stable monolithic quad timers produce 4 independent timing functions. These general-purpose controllers can be used in a monostable mode to produce accurate time delays from μsec to hours. Astable operation is achieved by using 2 of the 4 timer sections. The NE/SE553 output sinks current, while the NE/SE554 sources current. Both timers have an output current capability of 100 mA and require no coupling capacitors when connected in tandem. $1.86 (100) in a 16-pin DIP. Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. Phone(408)739-7700. **INQUIRE DIRECT.**



LED DIGIT DRIVER OFFERS IMPROVED NOISE MARGINS. The circuit consists of 6 MOS-compatible digit drivers, with each driver capable of sinking up to 320 mA. This bipolar IC offers increased battery life in multiplexed LED battery applications. A separate pin is provided on the BD5021 for driver current input. Current flow is prevented if the input potential becomes negative, assuring adequate noise margins when key closures place negative potential on return lines. Available in 16-pin DIP. $1.20 (1000). Bowmar Arizona Inc., 2355 W. Williams Field Rd., Chandler, AZ 85224. Phone(602)963-7361.
Circle No. 196

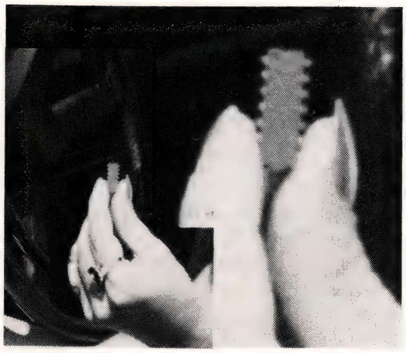
4k RAM USES N-CHANNEL PROCESS. A replacement for magnetic core memory elements, designated RM1701H, has been introduced. Organization is 4096×1 with a 16-cycle refresh. The device features single clock input, 400 mW operating and 2 mW standby power. Access time is 300 nsec max., with a 470 nsec max. cycle time. All inputs (except clock) are TTL compatible. Packaging is in a 22-pin DIP. $27 (100). Western Digital Corp., 3128 Red Hill Ave., Box 2180, Newport Beach, CA 92663. Phone(714)-557-3550. **Circle No. 197**

FAST SILICON PLANAR DIODES OFFER QUICK RECOVERY TIME. Two series of feature fast-switching diodes PRV ratings up to 400V. The 6A diodes offer 125 nsec recovery time and the 12A, 150-nsec. Both series utilize epitaxial planar chip construction. The diodes are packaged in a DO-4 for chassis mounting. The 6A unit, designated SPD 605-640, is priced at $1.40 (100); SPD 1205-1240 is $1.65 (100). Solitron Devices, Inc., 1177 Blue Heron Blvd., Riviera Beach, FL 33404. Phone(305)848-4311. **Circle No. 198**

TWO MICROWAVE STRIPLINE SCHOTTKY DIODES INTRODUCED. Designed to operate in the 1-12 GHz range, these diodes are in hermetic packages. Model 5082-2200 has a max. noise figure of 6 dB and a VSWR of 1.5:1. The 5082-2202 features a noise figure of 6.5 dB with a VSWR of 2.0:1. Matched pairs of each model are available. Assembly uses passivated silicon Schottky-barrier beam-lead diodes. $28.35 and $23.75 (1-9), respectively. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304. Phone(415)493-1501.
Circle No. 199

3A RECTIFIERS COST LESS. The medium-power silicon rectifiers feature a high surge current with 150A max. and peak reverse voltage through 1000V. The 30S series is designated as a replacement for glass, epoxy, encapsulated and metal rectifiers. International Rectifier, 233 Kansas St., El Segundo, CA 90245. Phone(213)678-6281. **Circle No. 204**

RUGGED POWER TRANSISTORS ARE ECONOMICALLY PRICED. Registered as the 2N5666 and the 2N5667, these transistors feature high-speed switching characteristics. Packaged in a TO-5 can and rated at 200 and 300V BV_{CEO}, the units are capable of handling 10A current pulses. $9.75 and $12.90 (1-99), respectively. Kertron Inc., 7516 Central Industrial Dr., Riviera Beach, FL 33404. Phone(305)848-9606. **Circle No. 200**



OP AMPS OPERATE FROM A SINGLE POWER SUPPLY. These dual and quad op amps use lower power than their predecessors. Total current drain of the LM324 is 800 μA at 5V. $2.50 (100). Current drain of the NE532 is similar at 100 μA/amplifier. $1.05 (100). Both devices operate from a single source of 3-30V and have a unity gain bandwidth of 1 MHz. Input offset is 2 mV with a low bias current of 45 nA. Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. Phone(408)739-7700. **INQUIRE DIRECT.**

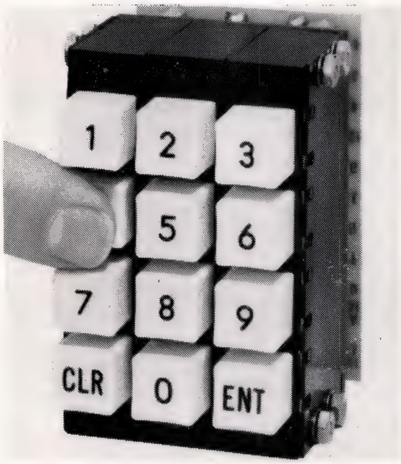
HIGH-VOLTAGE DRIVERS OFFER LOW NOISE. Dual peripheral drivers have been developed with double the voltage capability of existing monolithic devices. The LM3611 (dual NAND driver) series contains a pair of TTL gates driving 300 mA, 80V power transistors. Breakdown voltage of the family is 80V min. with a delay time of about 130 nsec. The LM3611, 3612 dual NAND driver, 3613 dual OR driver and the 3614 dual NOR driver are all available in 8-pin minidip's. $1.90 (100). National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone(408)732-5000.

Circle No. 201

2.5-MHZ TRANSISTORS FOR CLASS A OPERATION. Designated for oscillators and class A linear service, both transistors are gold metallized and emitter ballasted. The PH8193 is housed in a TO-46 hermetic package and can produce 300 mW at 1.75 GHz, 17V. $13.50 (100). PH5110 is packaged in a common-emitter isolated stud stripline package. Rated for 0.5W at 2.3 GHz and 18V, the cost is $27 (100). Power Hybrids Inc., 1742 Crenshaw Blvd., Torrance, CA 90501. Phone(213)320-6160.

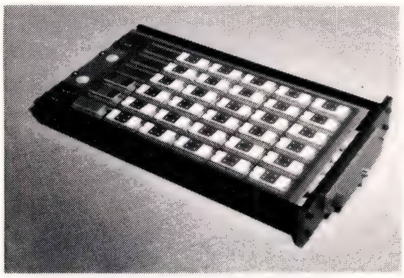
Circle No. 202

For more information, Circle No. 51

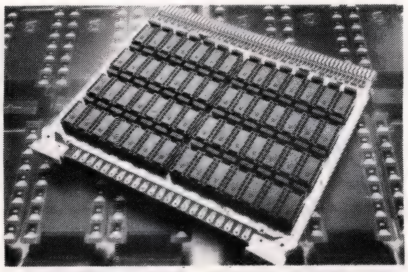


ILLUMINATED SOLID-STATE KEYBOARD HAS HIGH RELIABILITY. Solid-state design eliminates contact bounce, internal resistance and mechanical variables. Each keytop is removable, permitting lamp replacement from the front. Connections and outputs are provided with pc-board terminations at the back of the assembly. These avionic keyboards meet military environmental requirements of MIL-E-5400. Symbolic Displays, Inc., 1762 McGaw, Irvine, CA 92705. Phone(714)546-0601.
Circle No. 205

CARDREADER AND PRINTER INTERFACES SERVE MINI'S. Model 2310 will interface line printers by Tally, Data Products, Centronics, Printec and Potter to mini's by Data General, DEC, Hewlett-Packard, DCC, Varian and Honeywell. $750. Model 2510 interfaces card readers by Documation, Bridge, Peripheral Dynamics and True Data to the same mini's. Both interfaces are compatible with the main frame manufacturer's software. Media III, 2259 Via Burton, Anaheim, CA 92806. Phone(714)870-7660. **Circle No. 206**

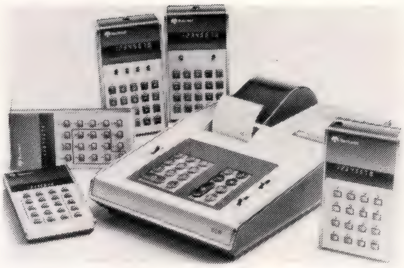


SWITCHING SOPHISTICATION AT ITS BEST USES CMOS. "Interconnect Switch" is a solid-state switching array with 256×256 addressable and selectable combinations. Each of the 256 input channels has a unique 8-bit binary address. Any 2 addresses will place an input channel on each of 2 buses (A and B) for output termination. Digital data up to 30V p-p at 5 MHz can be transferred at an addressing rate of 2 MHz. $2600. Counterscan Systems, Box 536, E. Hwy. 6, Sutton, NB 68979. Phone(402)773-3875.
Circle No. 207



VERY LOW-NOISE SOCKET CARDS ARE MADE FOR 14-PIN DIP'S. One ceramic bypass capacitor/socket, plus 2 low-frequency decoupling capacitors/card, are featured on EECO socket card 3D2013. It is available with a 120-pin connector or with 106-pin 2-piece connectors—both with either 2- or 3-level wire-wrap pins. Made of glass epoxy with 2-oz. copper etch, the cards feature extracting handles, 22 test points and a plastic pin and wiring shield. $160. Electronic Engineering Co. of California, 1441 E. Chestnut Ave., Santa Ana, CA 92701. Phone(714)835-6000.
Circle No. 208

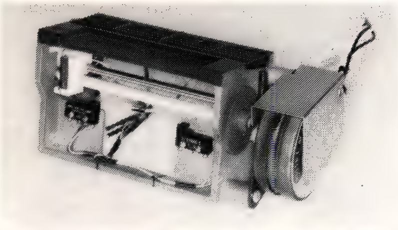
COMPACT LOW-COST CRT DATA TERMINAL OFFERS OPTIONS. The Mini-View offers a low-profile keyboard, protected fields and space suppression. Also lower case codes may be read and displayed as upper case characters with speeds up to 9600 baud. Other features include cursor keyboard control, address and readout; tabbing, blink features and a programmable read function. $1695 (lease starts at $65/mo.) Randal Data Systems, 2807F Oregon Ct., Torrance, CA 90503. Phone(213)320-8550.
Circle No. 209



ALL IN THE FAMILY WITH ROCKWELL CALCULATORS. Designed for a broad spectrum of needs, this line includes models from a 4-function unit for $29 to a desk-top printer for $169. And if logs, roots and trig are your business, they offer you the 202 Slide Rule as a partner. Also offered is the 203, a "shiny new convertible" that gets 3.7954 liters/gal., and the 204 financier that does everything but lend you money. Microelectronics Division, Rockwell International, Box 3669, 3430 Miraloma Ave., Anaheim, CA 92803. Phone(714)632-3563.
Circle No. 210

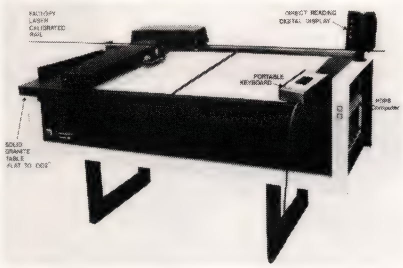
"OFF THE SHELF" KEYBOARDS. The ASR 33/20 is a basic ASR-type alphanumeric keyboard with an added 20-numeric-key pad. The customer can determine pad size by removing any number of keys and replacing them with dummy core modules. The keyboard's heart, a ferrite-core switch tested to over 100M operations, has only 1 moving part and features low-profile styling. Licon Div., Illinois Tool Works Inc., 6615 W. Irving Park Rd., Chicago, IL 60634. Phone(312)282-4040. **Circle No. 211**

DYNAMIC TEST PROBES TROUBLESHOOT ALL LOGIC FAMILIES. These pocket-sized digital probes, powered by the unit under test, are for field and shop troubleshooting of N/C devices, computers, business machines and telephone systems. Probe series DTP-3 is for DTL and TTL families; DTP-4 for HTL; DTP-5 for RTL; and DTP-6 and DTP-7 for CMOS. They indicate logic ONE, ZERO and other conditions using 3 color-coded lamps. Series DTP-7 has a LED display. $44 to $109. A P Products Inc., Box 110, 72 Corwin Dr., Painesville, OH 44077. Phone(216)354-2101.
Circle No. 212

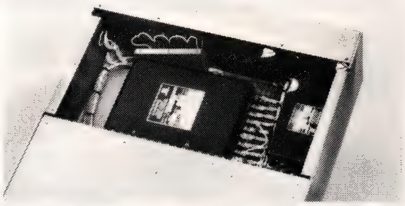


MAGNETIC STRIPE READER FITS OEM NEEDS. The unit can encode or read data from the magnetic strip on credit cards in accordance with ANSI Standard X4.16-1973 to the requirements of ABA, IATA or Thrift Industry specifications. Its reader mechanism ensures positive tracking of data on damaged or warped credit cards. Interbit jitter has been cut to <1.5%. The reader converts the magnetic encoding to a clocked digital, bit serial signal. $90. Elcom Industries, Inc., 10277 Bach Blvd., St. Louis, MO 63132. Phone(314)429-3100.
Circle No. 213

METRASCOPE MEMORY GIVES INSTANT REPLAY. The M/S 20D scans up to 80 channels of information, compares the readings to up to 4 preset alarm levels, provides a CRT bargraph display of the data and annunciates off-normal conditions. Any CRT bargraph display may be stored and recalled without interrupting the scanning, alarming or annunciating functions. Input and output to the memory are both asynchronous and independent from each other. Metra Instruments, Inc., 1340 Space Park Way, Mt. View, CA 94043. Phone-(415)961-7249. **Circle No. 214**

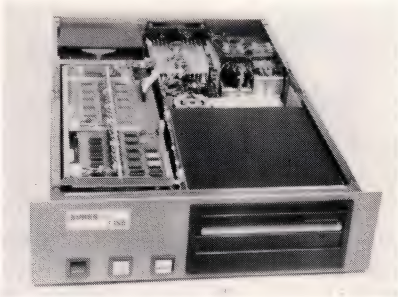


COMPUTER AND LASER GUARANTEE PRECISION DRAWINGS. The Linemaster plotter swiftly produces charts, die and mold layouts, or any drafting assignment to ±0.001 accuracy. Using a keyboard, the operator controls the plotter drive via a PDP-8 computer that provides linear and circular interpolation. The Linemaster works to any scale multiplier from 0.001 to 99.999, with a resolution of 0.0005 in. Its laser-calibrated granite table accommodates drawings up to 33×50 in. Andrew Engineering Co., 5520 S. County Rd. 18, Hopkins, MN 55343. Phone(612)938-2767. **Circle No. 215**



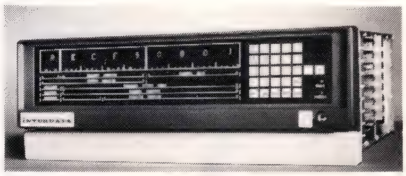
PMOS MEMORY SYSTEM OPERATES IN SEVERE ENVIRONMENTS. Semistore III, based on a 1024×1 PMOS dynamic RAM, is designed to meet MIL-E-16400 class 3 or 4 and MIL-E-5400 class 1A specs. Applications include buffering, data acquisition, display refresh, or main memory for airborne, shipboard or mobile units. With 385-nsec access and 500-nsec cycle time, it provides up to 786,000 bits of memory. Monolithic Systems Corp., 14 Inverness Dr. E., Englewood, CO 80110. Phone(303)770-7400. **Circle No. 216**

COMPUTER PRODUCTS

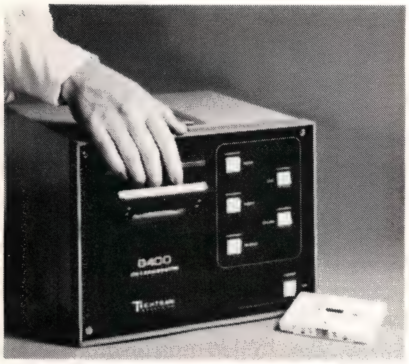


FLOPPY DISC READS/WRITES FOR MINI'S AT ANY PRIORITY LEVEL. SYKESdisk 7150 is an asynchronous and IBM-compatible flexible disc system. Dual sector buffers permit easy connection to transfer data in data-communication and data-collection applications. When used with a mini, its smart controller performs sector search, track sequencing, record blocking, generation and check of IBM sync and CRC characters, address verification, head unload and bootstrap. $2691. Sykes Datatronics Inc., 375 Orchard St., Rochester, NY 14606. Phone(716)458-8000. **Circle No. 217**

COMMUNICATIONS INTERFACE IS FOR THE NOVA. Featuring 8 serial I/O ports, the MCPI-1 interface allows up to 8 data terminals or computers of varying baud rates or code structures to communicate directly with a common mini. Transmit and receive rates are individually software programmable from 6 to 12,800 baud. The interface allows a Nova to interact with a teletypewriter of an on-line computer, or any RS-232 type modem. Code structures may have parity-checking. $2110. MetroData Corp., 1250 Mercer St., Seattle, WA 98109. Phone(206)329-9000.
Circle No. 218

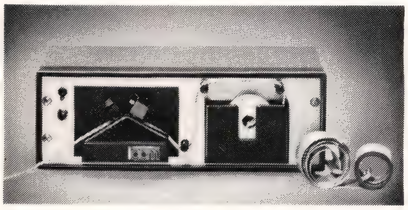


HIGH-SPEED ALU IMPROVES MINI'S PERFORMANCE LEVEL. This plug-in option, a high-speed arithmetic logic unit, provides hardware floating point, signed multiply/divide, list processing and privileged instruction detect. In addition, it improves all execution times by one third or more, and optimizes the Model 7/16 16-bit minicomputer's performance. HSALU plug-in, $4900. Mini model 7/16, with HSALU, $8100. Interdata, Inc., 2 Crescent Pl., Oceanport, NJ 07757. Phone(201)229-4040.
Circle No. 219



CASSETTE RECORDER OFFERS HIGH PERFORMANCE AT LOW COST. The 8400 features storage of 145,000 characters/cassette, selectable baud speeds and remote control. With automatic search at 1000 c/sec this recorder allows data edit access for character and line correction. Portable, it is compatible for on-line connection to CPU's through modems or acoustic couplers. The unit weighs 15 lbs. $889. Delivery is 45 days ARO. Techtran Industries, Inc., 580 Jefferson Rd., Rochester, NY 14623. Phone(716)271-7953. **Circle No. 220**

3-CHIP SET PROVIDES 40 KEYS OF MATH FUNCTIONS. Dubbed the "Senior Scientific," this set permits the solution of advanced mathematical, statistical or scientific problems. The first 2 chips provide basic arithmetic, algebraic and transcendental functions, with a 14-digit display and memory. The third array includes factorial, binomial coefficient, probability integral and statistical functions. $50. MOS Technology, Inc., 950 Rittenhouse Rd., Norristown, PA 19401. Phone(215)666-7950.
Circle No. 221



DEDICATED MICROPERIPHERAL™ LOADS ASSEMBLER IN 120 SEC. iCOM model R8016P high-speed paper tape reader is compatible with National's IMP-8P and IMP-16P microcomputers. Features include paper tape software and interfacing 40-line ribbon cable with plug. Eight times faster than the Teletype™, the reader includes a pROM driver, a diagnostic tape and BNPF pROM tapes. It measures 17×8×5-1/4 in. $995. iCOM, Inc., 6741 Variel Ave., Canoga Park, CA 91303. Phone(213)348-1391. **Circle No. 222**

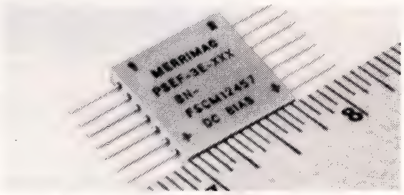
12-BIT DAC COMBINES HIGH PERFORMANCE WITH LOW COST. The DAC1118 includes an input storage register, an output amplifier with 5 programmable output voltage ranges, and performance of ±20 ppm/°C gain TC and 5 μsec settling time to 0.01%. Specified for operation from 0 to +70°C, it has ±1/2 LSB max. linearity error and ±2 ppm/°C differential linearity TC. $112. Analog Devices, Inc., Route 1 Industrial Park, Norwood, MA 02062. Phone(617)329-4700. **Circle No. 223**

HYBRID REGULATORS OFFER NEGATIVE AND POSITIVE OUTPUTS. LAS4000 Series (neg.) and LAS6000 Series (pos.) both contain 5 and 9-pin models. LAS4000 voltages range from −5 to −28V, currents from 4 to 15A, and wattage from 170 to 240W. LAS6000 figures are +5 to +28V, 8 to 25A and 310 to 380W. $37-$43 (LAS4000), $47-$56 (LAS6000) in 1000-pc. qty. Lambda Electronics Corp., 515 Broad Hollow Rd., Melville, NY 11746. Phone(516)694-4200. **Circle No. 224**

SYNCHRO-TO-DIGITAL CONVERTERS REQUIRE NO TRIM OR ADJUSTMENT. All standard models of Series 168B function at both 60 and 400 Hz. They accept both 26 and 115V reference and both 11.8 and 90V stator inputs. Accuracy is ±4 minutes ±0.9 LSB at 25°C, with 14-bit resolution. Models may be selected to provide error-free tracking to 3600°/sec. $550 (Model 168B100) Control Sciences, Inc., 10315 Woodley Ave., Granada Hills, CA 91344. Phone(213)342-3067. **Circle No. 225**

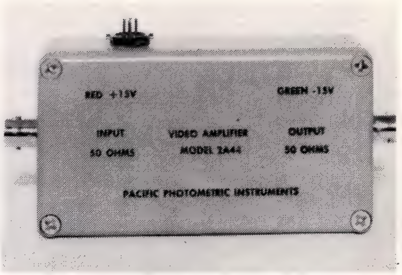
PHASE-TO-VOLTAGE CONVERTER PROVIDES ACCURATE OUTPUT. Model 792 generates a dc output proportional to the phase difference between 2 ac input signals. Output is −5 to +5V with ±1% accuracy. Input phase can extend from −360 to +360°. Signal input freq. range is 100 Hz to 300 kHz. Output is linear to within ±0.5% of full scale. $147(100). Solid State Electronics Corp., 15321 Rayen St., Sepulveda, CA 91343. Phone(213)894-2271. **Circle No. 226**

OP AMPS COMBINE FAST SLEW RATE WITH WIDE BANDWIDTH. The SG118/218/318 high-speed op amps feature slew rates to 70V/μsec and bandwidths of 15 MHz. Typ. input characteristics include 2-mV offset voltage, 6-nA offset current and 120-nA bias current. Voltage gain is typically 200,000 over a supply voltage range of ±5 to ±20V. The series is offered in 3 package styles and 3 temp. grades. $2.70 to $22.95(100). Silicon General, Inc., 2712 McGaw Ave., Irvine, CA 92705. Phone(714)556-1600. **Circle No. 227**



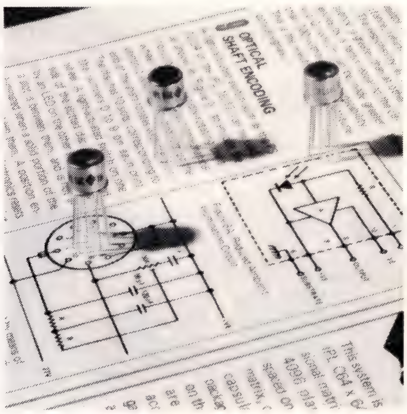
FLAT-PACK PHASE SHIFTERS COVER 10-500 MHz RANGE. PSEF-3E devices have a phase shift range at center freq. of 0 to −180° and 10% bandwidths. 3 standard models have center freq. of 30, 60 and 160 MHz. Other specifications include insertion loss of 1.2 dB max., VSWR of 1.6:1 max. with impedance of 50Ω, input power of −10 dBm and phase stability of ±5° typ. $145 with delivery 45 days ARO. Merrimac Industries, Inc., 41 Fairfield Place, West Caldwell, NJ 07006. Phone(201)228-3890. **Circle No. 228**

HYBRID DC CONVERTERS DESIGNED FOR AUTOMOTIVE ELECTRONICS. With a standard 12V dc automotive power input, Model PS152OD produces +200V dc, unregulated, at 14 mA. Multiple output model PS1652M produces +250V dc at 30 mA, +5A at 160 mA and −12V dc at 50 mA. Model PS1603F accepts +12V dc input and creates a regulated −12V dc output at 50 mA. Both commercial and military versions are available. LRC, Inc., 1001 Digital Dr., Hudson, NH 03051. Phone(603)883-9351. **Circle No. 229**



VIDEO AMPLIFIER DESIGNED FOR USE WITH PHOTOMULTIPLIER TUBES. Model 2A44 video amplifier features noninverted gain of 100 and operation from dc to 50 MHz. Input and output impedances are 50Ω. Rise and fall times are 5 nsec. Power requirements are ±15V at 100 mA. $150. Pacific Photometric Instruments, 5745 Peladeau St., Emeryville, CA 94608. Phone(415)654-6585. **Circle No. 230**

SOLID-STATE FLASHER DESIGNED FOR EASY PANEL MOUNTING. The FL 1-A is fully transistorized and designed to operate on 110V, 60 cycle line current with a load capacity of 300W on inductive or noninductive loads. Ratings up to 25A are available. The flasher operates at 120 flashes/min., with other flash rates available on request. $37.20. ECP Corp., 4726 Superior Ave., Cleveland, OH 44103. Phone(216)391-0444. **Circle No. 231**



ANALOG LIGHT DETECTORS OPERATE AS LIGHT-TO-VOLTAGE CONVERTERS. Each device in the IPL series consists of a photodiode integrated on a chip with a MOS buffer amp. The chip is mounted on a ceramic substrate which has a thick-film feedback resistor. The units have a response of <1 μsec and operate in a bandwidth up to 400 kHz. The feedback loop, left open for ac designs, can be closed for dc systems by shorting 2 pins. Integrated Photomatrix, Inc., 1101 Bristol Rd., Mountainside, NJ 07092. Phone(201)233-7200. **Circle No. 232**

MARK TEN B, THE GAS SAVING, PLUG SAVING, TUNE-UP SAVING, ELECTRONIC IGNITION FROM DELTA. NOW AS LOW AS $49.95.

Years of testing and use by race car drivers in all categories have proven Delta's Mark Ten B the most advanced ignition system on the market today.

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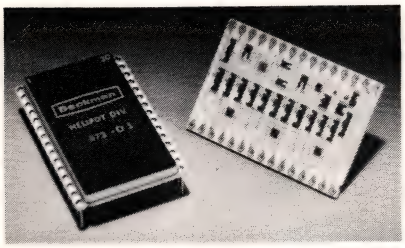
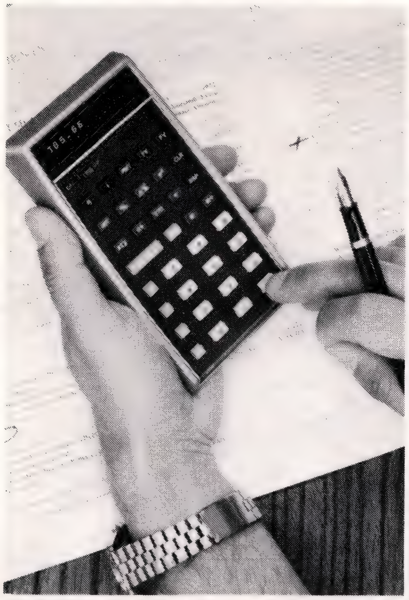
For more information, Circle No. 57

CONVERTER HAS HIGH ISOLATION AND LOW CAPACITIVE COUPLING. The UPM-5/5000-D5 dc/dc converter has $10^8 \Omega$ isolation and 250 pF coupling from input to output. Noisy or unregulated inputs of −4.5 to +5.0V dc are transformed to +5V dc ±1% with 200 ppm/°C TC. The unit can also be used to develop −5V from +5V input. It uses high freq. switching with transformer isolation to achieve efficient conversion. $79. Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021. Phone(617)828-8000.
Circle No. 233

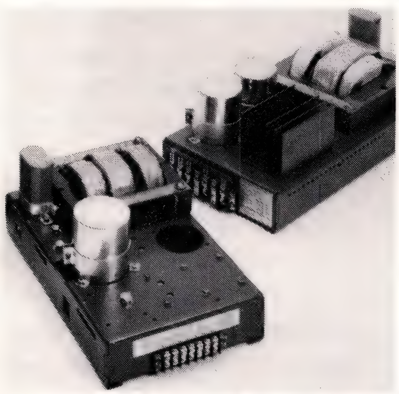
WIDEBAND IF DELAY LINES SIMPLIFY SYSTEM DELAY TRIMMING. Delay values for the Model BID-600 are 0.25 to 8.0 μsec in binary steps. Center freq. is 60 MHz, with a 3 dB bandwidth of 30 MHz. Amplitude ripple, across the bandwidth, is ±0.2 dB with attenuation equal to 20 dB max. VSWR, for both input and output, is 1.4:1. From 0 to 50°C, delay variation is ±0.005 μsec, amplitude variation is ±0.5 dB. CW input power is +25 dBm max. Walther M.A. Anderson and Assoc., Inc., 4 Main St. Ext., Tariffville, CT 06081. Phone(203)658-7666. **Circle No. 234**



12-BIT BINARY DAC DESIGNED FOR CMOS LOW-POWER APPLICATIONS. Series 872 feature CMOS switching, an R-2R binary ladder, an output buffer amp. and an internal ±10V precision reference. Model 872-D1 accuracy code guarantees ±1/2 LSB in 10 bits; Model 872-D2 guarantees ±1/2 LSB in 9 bits. Both units have operating temp. range of −55 to +125°C, and typ. offsets of ±1.0 mV. They can be connected for either 0 to +10 or 0 to −10V scale range. $88 (872-D1) and $66 (872-D2). Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, CA 92634. Phone(714)871-4848.
Circle No. 235

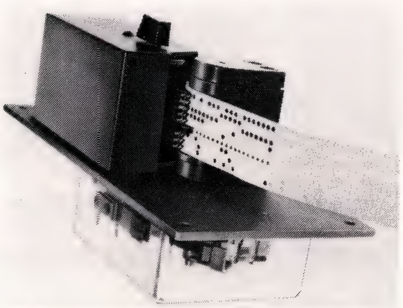


POCKET BUSINESS CALCULATOR HOLDS INTERMEDIATE RESULTS. The 9-oz. HP-70 solves common financial calculations. In addition to the 4 basic arithmetic functions, 21 of the most common equations used in business and personal finance have been programmed into it. It features a 4-memory operational stack as well as 2 independent memories for intermediate storage of numbers, and can accumulate 2 running totals concurrently. $275. Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. Phone(415)493-1501.
Circle No. 259

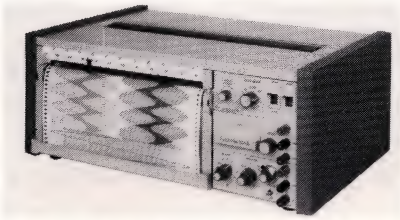


LT SERIES OF OPEN-FRAME POWER SUPPLIES INCREASES BY 14. "E" size (4-15/16H×7-1/2W×11-3/4D) now includes models providing from 5V @ 22A to 28V @ 8.4A. Capacities of "EE" size units (4-15/16H×7-1/2W×16-1/2D) are from 5V @ 32A to 28V @ 12A. Features include efficiencies to 55%, line regulation of 0.02%, load regulation of 0.15% and ripple of 1.5 mV rms. $190 and $275 (E and EE, respectively). Lambda Electronics Corp., 515 Broad Hollow Rd., Melville, NY 11746. Phone(516)694-4200.
Circle No. 260

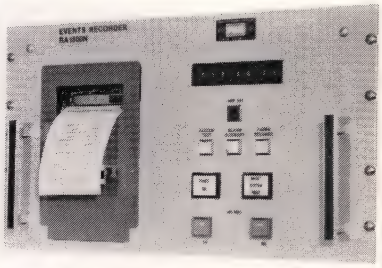
METER DIRECTLY READS BOTH ENERGY AND POWER OF LASERS. Range of the Model 504B is from 100 mJ to 300J and from 100 mW to 300W. For energy measurements, it is used with the Quantronix Model 500 receiver; for power measurements, with the Model 502 receiver. The meter measures, with 2% accuracy, CW or pulsed laser energy of Argon, Nd:YAG, Ruby, CO_2 and other lasers. $715. Quantronix Corp., 225 Engineers Rd., Smithtown, NY 11787. Phone(516)273-6900. **Circle No. 261**



STAR-WHEEL SENSING AND SOLENOID DRIVE IN PAPER-TAPE READER. The Model 30A features reduced noise level and is claimed to outperform competitive units in both specifications and reliability. It was designed for low-speed applications. Electro Mechanisms, Inc., Box 371, Wayne, NJ 07470. Phone(201)696-1986. **Circle No. 262**



10-IN. STRIP-CHART RECORDER PROVIDES 250-mSEC RESPONSE. Available with 1 or 2 pens, Model 110 is especially suited for long-term, attended or unattended monitoring of low-frequency signals. Its thermal writing system produces clear, blue, highly reproducible traces. Single and multi-span preamps provide sensitivities from 100 μV to 100V F.S. Switch-selectable chart speeds range from 1 in./hr to 8 in./min. Gould, Inc., Instrument Systems Division, 3631 Perkins Ave., Cleveland, OH 44114. Phone(216)361-3315.
Circle No. 263



NUMERIC-PRINTOUT SEQUENTIAL EVENTS RECORDER IS COMPACT. The OEM model RA-800N consists of 2 off-the-shelf modular components: a contact processing unit (CPU) and an input contact unit (ICU). The CPU has a capacity for up to 500 inputs and is furnished with a standard sequential memory of 64 levels (optionally expandable to 128). It scans each input once every msec and prints out events in real-time alphanumeric code on an integral line printer. Rochester Instrument Systems, Inc., 275 N. Union St., Rochester, NY 14605. Phone(716)325-5120. **Circle No. 264**

FUNCTION GEN HAS INTERNAL SWEEP AND AM/FM MODULATION. The 3312A's 2 generators provide sine, square, triangle, pulse and ramps as well as internal sweep, trigger, gate or burst. The main generator covers 0.1 Hz to 13 MHz, and the modulator generator 0.01 Hz to 10 kHz. Output of the main generator is 10V p-p (50Ω). Dc offset of up to 10V p-p is included. Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. Phone(415)493-1501.
Circle No. 265

POTENTIOMETRIC SOUND LEVEL RECORDER KEEPS OVERSHOOT LOW. The ruggedized Model 2766 is designed for portable use. Its high-torque servo-drive measuring system reduces overshoot. Inkless recording in dB, at 600 mm/hr is standard. The unit is also compatible with all sound-level meters having outputs of 0.5 to 3V. Size is 3-3/4×6×9-5/8 in. and weight is 9-1/2 lbs. Simpson Electric Co., 853 Dundee Ave., Elgin, IL 60120. Phone(312)695-1121.
Circle No. 266

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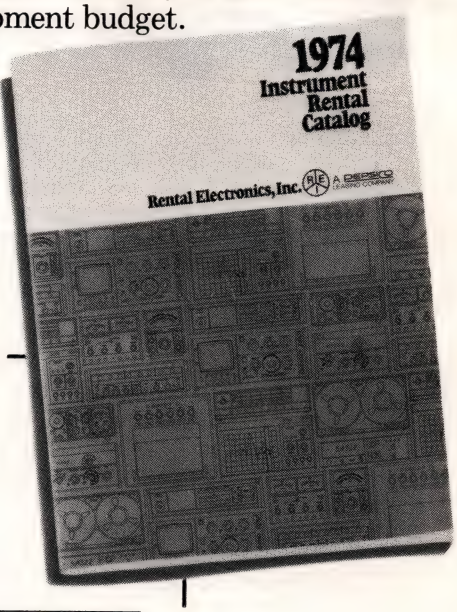

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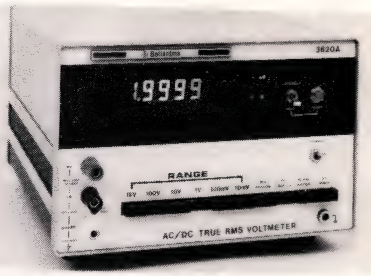
COMPACT DIGITAL THERMOMETERS EMPLOY INCANDESCENT READOUTS. Requiring minimum panel space or volume, Series 3000 units handle up to 6 remote channels. Their readout employs RCA Numitrons. Available ranges encompass −300 to +600°F (−200 to +300°C) with 1° resolution, or −200 to +200° (either °F or °C) with 0.1° resolution. Input voltages from 12V dc to 230V ac are offered. Panel-mounted unit, $349. Victory Engineering Corp., Victory Rd., Springfield, NJ 07081. Phone(201)379-5900. **Circle No. 267**

LSI/CMOS GIVES COUNTERS 100-nSEC TIME RESOLUTION. Four models, with frequency ranges from 10 Hz to 80, 200, 520 and 1000 MHz, have 9-digit "mini planar Pandicon" gas-discharge displays. The input signal is attenuated to a level just above 5 or 6 mV, which provides a 62-dB dynamic range. The PM6610 family can do frequency, single period, period average, totalizing and multiple ratio measurements. From $790 to $1750. Philips Test & Measuring Instruments, Inc., 400 Crossways Park Dr., Woodbury, NY 11797. Phone(516)921-8880.

Circle No. 268

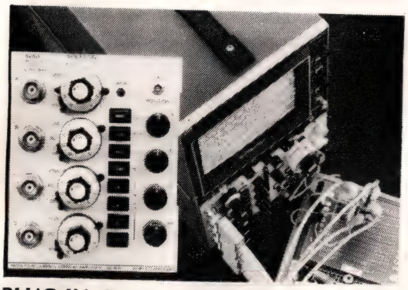


TRUE-RMS AC/DC DVM OFFERS 1 μV RESOLUTION. Capable of measuring ac and dc voltages and mixtures of the two, Model 3620A spans from 10 mV to 1 kV F.S. It features 4-1/2 digits (19999 count), a backlighted LCD, a 4-terminal guarded and floating input, overload protection to 1 kV on all ranges and typical accuracy of ± (0.1% of rdg. +0.1% F.S.). $1395. Ballantine Labs., Inc., Box 97, Boonton, NJ 07005. Phone(201)335-0900.

Circle No. 269

TRIPLE-OUTPUT P.S. FEATURES 0.1% DUAL TRACKING ON ±15V. Outputs are 5V @ 6A for logic circuitry and dual-tracking ±15V @ 1.5A for op amps and MOS. Other features are ±0.01% line regulation, ±0.02% load regulation and 0.01%/°C temperature coefficient. Current limit/foldback protection is built-in, and full power is available from 0 to 50°C. Model CBB-75W is $91.95 with OVP available at $7.95 extra. Power-One Inc., 531 Dawson Dr., Camarillo, CA 93010. Phone(805)484-2806. **Circle No. 270**

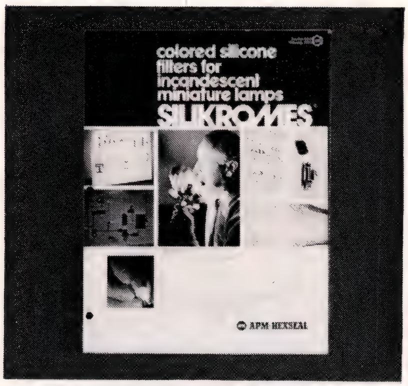
DYNAMIC BURN-IN SYSTEM HANDLES 1024-BIT MOS MEMORIES. Model 707-241 (MEM 1024) is equipped with plug-in cards to accommodate 80 test positions. It actively exercises the memory while holding it at elevated temperatures. LED's indicate a shorted input or other failure. Including clock, power supplies and logic circuitry, $9000. Aerotronic Associates, Inc., Riverside Dr., Contoocook, NH 03229. Phone(603)746-3141.
Circle No. 271



PLUG-IN GIVES OSCILLOSCOPE FOUR 100-MHz CHANNELS. Any of the HP 180-series scopes (180C, 181A, 182C, 184A etc.) becomes a 4-channel one when equipped with the Model 1809A vertical amplifier plug-in. Dc coupling, 10 mV/div. deflection factor and high chop rate (500 kHz for 4 channels, 1 MHz for 2 channels) suit it for high-resolution timing measurements in digital circuits. $2100. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304. Phone(415)493-1501. **Circle No. 272**

PHOTO-TACHOMETER MEASURES SPEEDS UP TO 50,000 RPM. The battery-operated hand-held Model 410 operates by counting the alterations of light and dark as a chalk mark rotates on a shaft. The sensor has a built-in light source and pick-up head that conveniently swivels 180°. Weight is a little more than 1/2 lb. $190, complete with batteries, carrying case and operator's manual. Simpson Electric Co., 853 Dundee Ave., Elgin, IL 60120. Phone(312)695-1121. **Circle No. 273**

SENSITIVE 5-FUNCTION MINI-MULTIMETER AUTORANGES. Boasting 10 μV sensitivity on dc V, Model 6355 combines 5 functions (dc V, ac V, Ω, dc I and ac I) in a single miniature unit. It operates on NiCad or alkaline batteries. Total weight is only 800g. $279 complete with alkaline battery cartridge and ac adapter. Delivery in Dec. '74. T.R.I. Corp., 505 W. Olive Ave., Sunnyvale, CA 94086. Phone(408)733-9080.
Circle No. 274



LAMP FILTERS. A 4-pg., color brochure, SK-8, gives complete technical information on Silikromes[R] color filters for incandescent miniature lamps. Included in this illustrated brochure are specifications, MIL color guides, and bar charts comparing life characteristics of bare vs. filtered lamps. APM-Hexseal, 44 Honeck St., Englewood, NJ 07631.

Circle No. 236

PHOTOGRAPHIC MEASUREMENTS. App note #30T1.1 describes how to use the J16 digital photometer/radiometer for photographic exposure measurements. It discusses averaging readings for a wide-angle camera lens, and estimation of exposure settings using reflectance from a scene. Graphs are included for converting scene luminance readings to shutter times and f numbers for various ASA film speeds. Tektronix, Inc., Box 500, Beaverton, OR 97077.

Circle No. 237

BRIDGES. This spec sheet compares—in 23 separate categories—14 bridge models manufactured by General Radio, Hewlett-Packard, E.S.I., Simpson and BECO. Comparisons made include range, accuracy, resolution, null detector sensitivity, available and required accessories, dimensions and price. BECO, 11003-118th Pl. N.E., Kirkland, WA 98033. **Circle No. 238**

TRANSISTOR REPLACEMENT. The "Transistor Substitution Handbook" guarantees the most accurate substitutions possible. All published specs for each bipolar transistor were fed into a computer, then each was compared with all the others. Section 1 contains substitutions for both U.S. and foreign transistors; Section 2 reviews the recommended applications. $2.95 ea. Howard W. Sams & Co., Inc., 4300 W. 62nd St., Indianapolis, IN 46206.

INQUIRE DIRECT.

STROBOSCOPY. This booklet, entitled "Stroboscope Model 30-K," discusses the theory and practice of stroboscopy in easy-to-understand terms emphasizing the importance of strobe use in a wide range of industrial and scientific applications. It also includes operating details, formulas for computing out-of-range RPM, and explanation of multiple-image ambiguity. Pioneer Electrical and Research Corp., 743 Circle Ave., Forest Park, IL 60130. **Circle No. 239**

'74-'75 PHONE DIRECTORY. In the Electronic Industry Telephone Directory, the White Pages contain approx. 20,000 listings of firms engaged in the manufacture, distribution and sale of electronic components, equipment and systems. Its Yellow Pages break down over 600 major product categories for buyers and engineers. $10 plus postage and handling. Harris Publishing Co., 33140 Aurora Rd., Cleveland, OH 44139.

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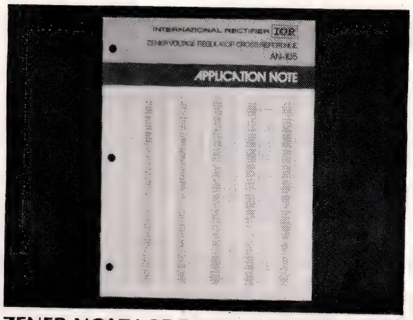
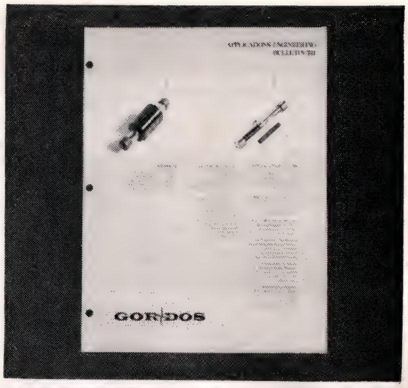


ZENER VOLTAGE REGULATORS. AN-105 cross references over 1800 parts, showing competitive and IR part numbers. Three charts list all IR-series regulators, voltage references and military qualified regulators. Each details characteristics such as power rating, zener voltage and case style. International Rectifier, Semiconductor Div., 233 Kansas St., El Segundo, CA 90245.

Circle No. 240

THICK-FILM DISCRETE RESISTORS. An all-inclusive, 24-pg. handbook, "Design Refresher on Metal-Glaze^{TM} Resistors," contains all the information necessary for finding, specifying and using thick-film metal-glaze resistive devices. Illustrated by product photos and drawings, charts, tables and graphs, the handbook gives complete product descriptions, applications and design information. TRW/IRC Resistors, 401 N. Broad St., Philadelphia, PA 19108.

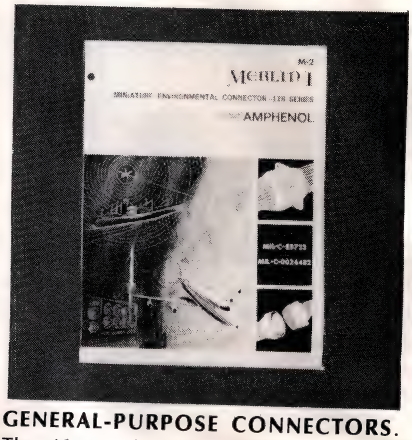
Circle No. 241



AXIAL-TRAVEL SWITCH. An 8-pg. applications bulletin gives technical information on the ATS 6000 Series miniature high-speed axial travel switch. The brochure also provides information on design features including the device's optimum "control density," mechanical and electrical design freedom, design support and dynamic characteristics. Gordos Corp., 250 Glenwood Ave., Bloomfield, NJ 07003. **Circle No. 242**

TEST EQUIPMENT. In 16-pgs., the 60-T covers general multi-purpose VOM's, laboratory and special features testers, G/P portables, temperature testers and accessories. Prices are given for all test equipment and accessories. The catalog also contains a handy selection guide chart designed to help select a tester for specific requirements. Triplett Corp., 286 Harmon Rd., Bluffton, OH 45817.

Circle No. 243

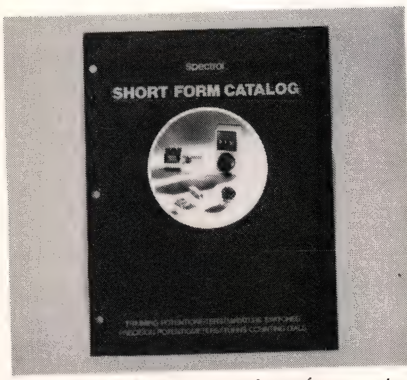


GENERAL-PURPOSE CONNECTORS. The 16-pg., full-color publication contains detailed performance specs, dimensional line drawings and cross-sectional views of "Merlin I" connectors. Twenty popular insert arrangements are fully illustrated in the catalog. For evaluation purposes, it also explains significant design features incorporated in Merlin connectors and their associated user benefits. Amphenol Connector Div., 2801 S. 25th Ave., Broadview, IL 60153. **Circle No. 244**

LINEAR IC'S. A quick-reference wall chart features capsule data and functional diagrams. Op amps, arrays, differential arrays, comparators and other devices are covered. RCA Solid State Div., Box 3200, Somerville, NJ 08876. **Circle No. 245**

HEAT SINK application handbook from Aham contains 152 pgs. of the written word, photos, graphs and applications. It discusses problem areas of heat sinking and how to solve them, and contains theorems and cost-saving methods. $1. Azusa Advertising, Box 243, Azusa, CA 91702. **INQUIRE DIRECT.**

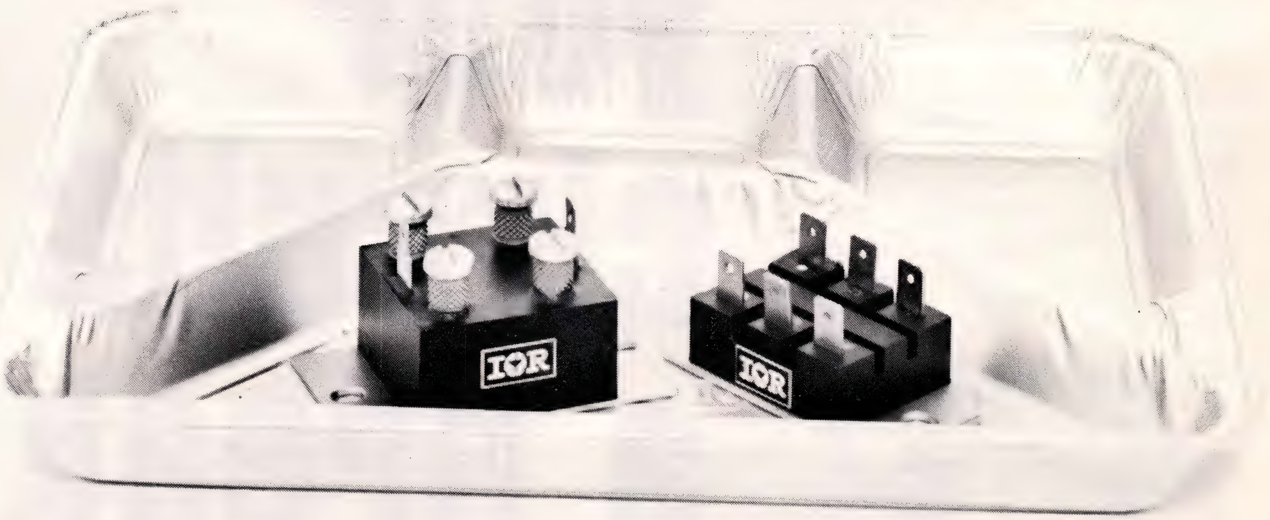
ANALOG AND DIGITAL Special Function Catalog contains design and application information on amps, buffers, comparators and other circuits. A cross-reference guide is included in these 200 pgs. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. **INQUIRE DIRECT.**



POTENTIOMETERS. A short-form catalog contains information on precision pots, trimming pots, concentric and digital turns-counting-dials, miniature switches and special potentiometer designs. It contains scaled photos of the products, specifications, and performance and application data. Spectrol Electronics Corp., 17070 E. Gale Ave., City of Industry, CA 91745. **Circle No. 246**

DIGITAL LOGIC ANALYZER. An 8-pg., 2-color brochure describes the MD-107 memory/digital logic analyzer. The brochure highlights 30 of the most important features of the new system, and carries an annotated photograph of the CRT readout along with a general description of the system. Macrodata Corp., 6203 Variel Ave., Woodland Hills, CA 91364. **Circle No. 247**

A new concept in packaged power circuits as convenient as the TV dinner.



The International Rectifier PACE/pak™ is the device behind this new concept.

They are power integrated circuits, made up of SCRs, diodes, triacs, etc. which give you a complete control circuit function in a single package. And like the TV dinner, they take most of the shopping and assembly times out of the job.

But that's just the beginning of the benefits they offer.

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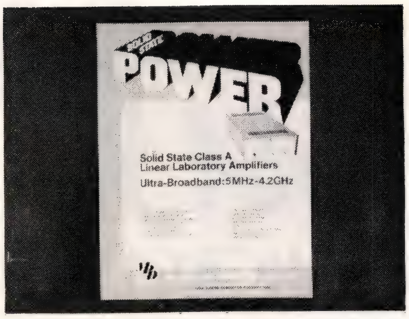
REGISTERED REFERENCE DIODES. A 4-pg. guide provides detailed data on jedec voltage-reference diodes. V_z values of 6.2 to 200V are covered. Codi Corp., Pollett Dr., Fair Lawn, NJ 07410.
Circle No. 248

PRODUCT/SYSTEM PACKAGES. Details of a full range of power system instrumentation, including transient recording and sequential event recording systems, annunciators, data loggers, supervisory control systems, protective relays and a variety of miscellaneous supplemental instrumentation are included in this 10-pg. catalog. Hathaway Instruments, Inc., 5250 E. Evans Ave., Denver, CO 80222. **Circle No. 249**

TIME DELAY RELAY CATALOG. The 7th edition of this 52-pg. catalog contains principles, applications, glossary and test procedures on time delay relays. Also listed are stock and special-order relays including solid-state/hybrids, thermal, air-dashpot, and copper-slug versions in all their styles and packages. Magnecraft Electric Co., 5575 N. Lynch Ave., Chicago, IL 60630.
Circle No. 250

INTEGRATED CIRCUIT INTERFACE. Linear, digital and MOS interface circuits are covered in this 400-pg. catalog. Technical and application notes along with a cross-reference guide are also included. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. **INQUIRE DIRECT.**

SAPPHIRE, and everything about it, is the subject of this 4-pg. reference source. The paper describes sapphire products and insulators, its usage in MIC, SOS and other hybrid circuit applications, optical sapphire products and optical applications. Bird Precision Jewels, 1 Spruce St., Waltham, MA 02154. **Circle No. 251**



AMPLIFIERS. A 4-pg. brochure contains specs and application data for wide-band solid-state linear Class A power amplifiers. It describes 54 models in full- and half-rack cabinets, spanning power levels of 1-20W, and operating at frequencies between 5 MHz and 4.2 GHz. Microwave Power Devices, Inc., Adams Ct., Plainview, L.I., NY 11803.
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PRECIOUS METALS. This 12-pg. brochure covers platinum, gold, silver and palladium in powder, flake and oxide form. It also describes special powder products and alloys. Details on particle shape, density, tap density, particle size and surface area are included. Metz Metallurgical Corp., 3900 S. Clinton Ave., South Plainfield, NJ 07080.
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MINI-UPS. The bulletin provides operating descriptions and diagrams of this miniature, uninterruptible power system. Specs, dimensions and weights are presented, as well as an open-door photograph of a MINI-UPS with call outs of components. Cyberex, Inc., 7171 Industrial Park Blvd., Mentor, OH 44060.
Circle No. 254

PACKAGING AEROSOLS. A 4-pg., 4-color catalog describes 5 aerosol products for packaging and shipping. Uses, characteristics and properties are given for each product, while photographs illustrate typical applications. 3M Co., 3M Center, St. Paul, MN 55101.
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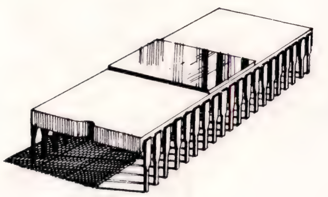
μP THE MICROPROCESSOR

a brief report on the first serious study of the design significance of the microprocessor and its impact on electronics and general industry



The EDN study of microprocessor applications is complete. It represents $20,000, and seven months of work by both EDN, Creative Strategies, and 1511 design engineers in the field. Construction of the questionnaire alone required four months and more than 100 interviews with marketing and technology authorities. The study, which included both mail and telephone interviews, was conducted for EDN by Robert F. Wickham of Creative Strategies and his staff. The complete report — including an executive analysis and summary, quantitative and verbatim results, and breakouts by four major criteria — covers more than 300 pages.

First . . . a word about the microprocessor

The advent of the microprocessor is the climax of a technological drama that began with the first electronic computer and the first use of a transistor in a computer. The microprocessor performs the functions of the Central Processing Unit — the arithmetic section, so to speak — of a computer, but it weighs a fraction of an ounce, measures less than a quarter of an inch square. Associated computer sections — control, timing, and memories are no larger than the microprocessor itself. Put them together in a single package smaller than the original transistor radios and you have a microcomputer. Because of the capabilities it provides in a minute package at modest cost the microprocessor is at the heart of a revolution so deep and so broad that it has, in one stroke, created entirely new markets for the electronic technology in every part of industry and personal life.

Battleground for a technological revolution

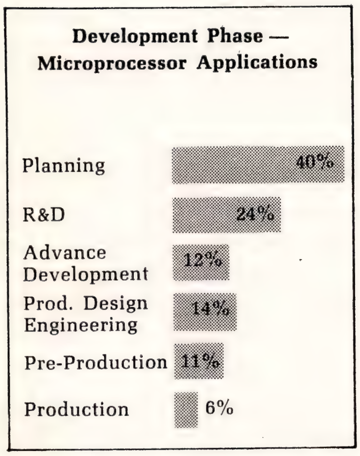
There seems to be no question that the potential areas of change related to the introduction of the microprocessor are all-pervasive. But it won't all happen at once. While the electronics industry has created the new technology, engineers in other industries will play a vital role in its application to essentially manual and electro-mechanical operations.

EDN editorial brought information on the capabilities of the microprocessor and guides to its successful use to its own audience of better than 250,000 designers and design managers in electronics. But until now little if any knowledge was available regarding the actual levels of interest, investigation, and application of the new technology in the new markets it opened up.

To develop this information, EDN editorial and research personnel, in cooperation with Creative Strategies, one of the best known and most knowledgeable of market research firms in the Bay area, undertook and sponsored a major study of the impact of the microprocessor. Here is a brief summary of the results of that study.

The new electronics . . . where? when?

The study confirms the pervasive promise of the technology. The applications — products and systems — for microprocessors number in the thousands, and the impact is just beginning to be felt. While 17% of respondents are currently designing with microprocessors, 53% have plans to use them or are in active evaluation.



Put another way . . . 6% of respondents have a product incorporating microprocessors in production now. 40% have such products in the planning phase.

In the vast majority of applications, microprocessor technology will replace hard wired logic . . . relay logic in about 10% of cases, minicomputers in another 20%. But significantly, 40% of respondents are investigating microprocessors for entirely new applications . . . not previously accomplished with electronics.

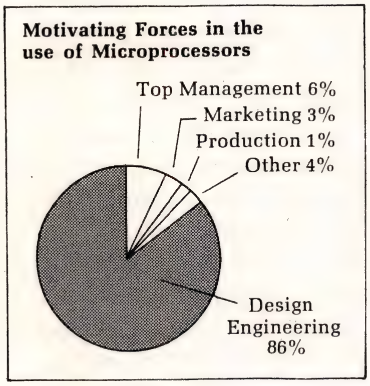
Microprocessors . . . which?

The 8-bit microprocessor is well on the way to being the standard device for the foreseeable future, but there is increasing interest in 16-bit capacity. Though 67% of current users are buying microprocessors at the chip level, there's a definite trend toward increased integration and purchases of complete microcomputer units. Most respondents will require semiconductor memories. Among peripherals, the greatest need is for numeric displays (57%) followed by keyboards (46%), A/D or D/A converters (36%), printers (33%) and modems (30%). Typical applications require three peripherals.

In evaluating microprocessors for purchase, the most significant single characteristic is availability, followed by supplier reputation and software support. The relative unimportance of product considerations — size, speed, etc. — though surprising, indicates that the application is often created around the microprocessor, rather than the reverse.

The Microprocessor . . . who?

The EDN study was conducted among design engineers. It's certainly possible that this biased the answers to at least one question: "Where did the motivation to use microprocessors originate?" Fully 86% said "design engineering". As it happens, however, this matches the opinions of virtually every expert in the field, including publishers of competitive magazines.



What You Can Learn From The EDN Study

This brief summary touches upon fewer than half of the questions asked in the study. The complete report . . . 300 pages of analysis cross-tabulation, and interview summaries . . . enables the reader to pinpoint the impact of the microprocessor upon exactly those product areas and market segments of greatest immediate interest to him. A copy of the report is available without charge to regular advertisers in EDN and to those companies which assisted in study development. Copies are otherwise available at $4.00 each. Just return the filled in coupon clipped to your letterhead.

Mr. Jerry Neth, Research Director
EDN, Cahners Publishing Company, Inc.
221 Columbus Ave., Boston, Massachusetts 02116

Dear Mr Neth:

Please send me a copy of the entire 300-page report on the EDN Microprocessor Study.

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signals and noise

Working effectively

Dear Sir,
This letter doesn't answer Walt Patstone's editorial's questions (EDN, Aug. 5, 1974), but it does address the larger problem: Assuming management is poor, can engineers assist their organization to nevertheless succeed?

Effective engineering organizations are not necessarily able. Much has to be said about the alternate lifestyle: the slowing of urbanization to a level more compatible with man's rate of evolution.

Therefore, with no hope of saving the world, I have to find my enthusiasm for engineering on a selfish basis. This is my first point: certain engineers work effectively because of selfish satisfaction gained. There is simply no other endeavor that provides as much challenge and sense of accomplishment for engineers like myself. Extending my definition of an effective engineer to apply to an effective organization, I conclude that an effective organization must be happy in its work. But an organization has no ability to make engineers effective or happy in their work. It goes the other way: effective individuals constitute the effective organization. To build an effective organization hire only those engineers that have demonstrated this selfish enthusiasm.

To better define an enthusiastic engineer, I offer this list of traits:

1. A continual curiosity and creativity that doesn't quit at 5 pm.
2. A continual dissatisfaction with how things are being done. (Edison: "There's a better way; find it.")
3. A desire to break through communication barriers to get the job done better. (A corollary: watch out for men that look good in meetings.)
4. An enthusiasm for writing letters and articles, however prejudiced, to fellow IEEE (or EDN or whatever) readership.
5. A paternal instinct to pass on and develop the above traits in subordinates and students.

My advice to any engineer who has these traits, but is externally unrewarded for them? Move on; your destiny is to be creative, not stable.

My advice to an organization who does not have enough (or is losing) enthusiastic engineers? Relax and fade away. It's too late; your former junior engineer ("wasn't he a troublemaker?") is building up a new organization just two blocks away.

If all of the above are too idealistic, I do have some practical advice for good engineers stuck in dead organizations: try moonlighting. The need for engineers exceeds the number of job offerings. Almost any organization needs part-time expertise. It is stimulating, rewarding and efficient. But, of course, keep it ethical.

Yours truly,
John Clothier, IEC

"IF YOU WANT A RECOMMENDATION FROM SOMEONE FAMILIAR WITH MY LINE, JUST PICK UP YOUR PHONE AND CALL YOUR WIFE."

An electronic affair

My Dear Pulsating Patty,

Darling, my love for you is like a wideband amplifier. Your beauty has me switched-on. My heart is beating in milliseconds. My logic memory has an open loop, caused by the pulsating waveform of your eyes. My noise immunity has reached a crescendo Its output impedance has triggered my offset voltage, never more to be reset by your decoder/driver. Your LSI has quad latched my CMOS. The result is plainly visible — a master-slave flip-flop! My access time is shorter, but your on-time is longer. The result — a differential or single-ended frequency drift combined into a monolithic phase-locked loop. How could this solid state change our interface relationship? No one can substantiate our slew rate. As always, when all else fails, love is the Schmitt trigger of our buffer interlock. And so, my love, a kiss, a sigh and good night!

All my love,
Eddy Current

Thanks for the kind words

Dear Mr. Forsberg:
Thank you for publishing my article "Do You Have What It Takes To BE an Effective Engineer?"

EDN does the best job of editing and illustrating articles compared to other journals that have published my material. Therefore, I prefer to offer other articles for consideration to EDN.

I have received much more feedback from co-workers and people from other companies. I believe your method of presenting articles is more effective than other approaches.

Sincerely,
Thomas T. Samaras
Claremont, CA 91711

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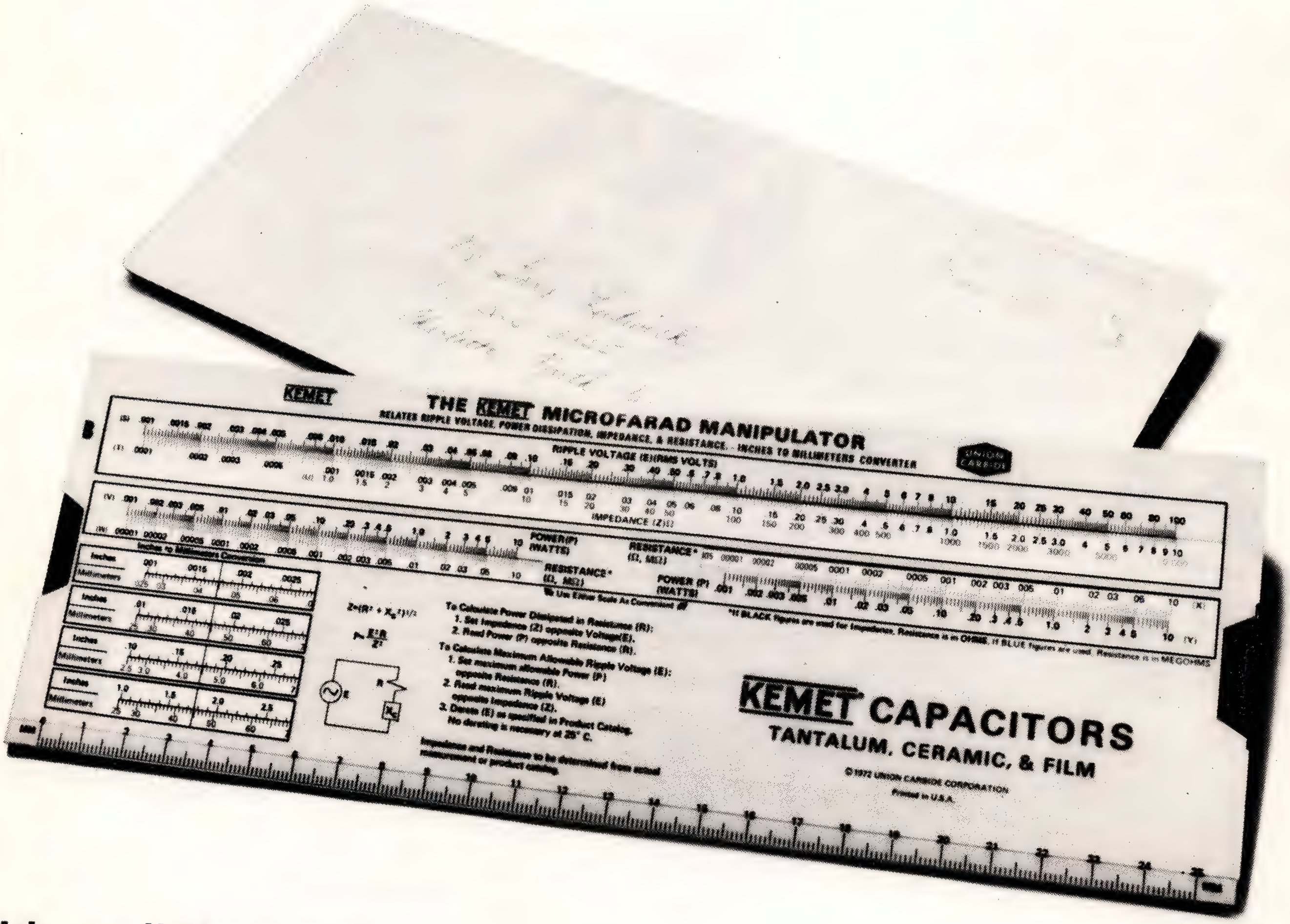

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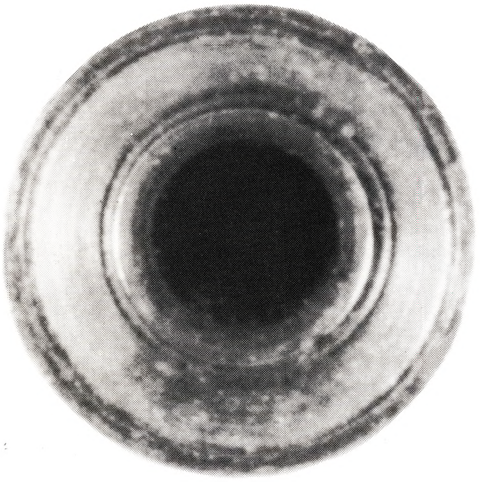

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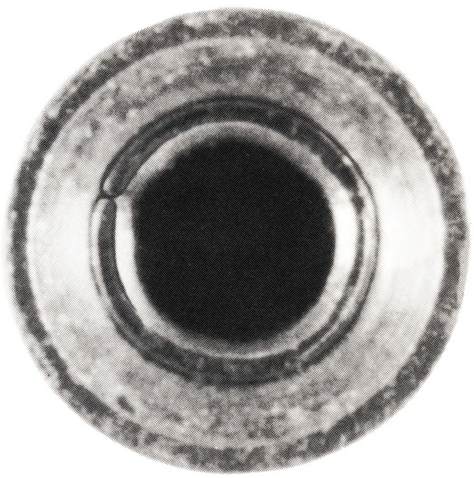

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